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PREFACE

Ever since the foundation of the Muir Central College in the early seventies of the last century, research work in various departments of studies has been carried on at Allahabad by several scholars. With the single exception perhaps of 'Indian Thought,' which was a quarterly journal of oriental research conducted by the late Dr. Thibaut and the undersigned, no attempt has hitherto been made to help the preservation or publication of the results of those researches. With the re-organisation of our University on the unitary basis, and the consequent stress laid upon research, it seems to be essential to provide for a vehicle for researches that are being carried on under the University. As a modest beginning we are publishing this year, a single number of our Studies, wherein are contained contributions from the several departments of the University.

It will be seen that all the departments of the University have not been able to send their contributions. It is hoped that this does not mean that these departments have done nothing worth publishing, and that it has been due to that lack of punctuality which hampers so much of our work; and yet we could not wait longer, as the Press was persistent in its demand for matter. This has also been the reason why we could not ask for and obtain contributions from our associated Colleges.

It is not easy to ascertain what position this Journal will win for itself in the world of scholarship and research. The price fixed for it therefore should be regarded as entirely provisional; it will depend upon the support that it secures for itself from the public.

GANGANATHA JHA,
Vice-Chancellor.

CONTENTS

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METEOROLOGY IN ANCIENT INDIA.

GANGANATHA JHA.

We have been taught to believe that Meteorology is a new science,—even in the West; and that in India it is something absolutely new. This notion, like many others relating to this unfortunate country, is based upon wrong assumptions. But the blame for this does not rest upon any body. It rests upon the circumstance that what we know of Meteorology is found in works relegated to the dubious realm of Astrology. And nobody has taken the trouble to look deeper and see if there is anything in those works beyond the oft-discredited subject of Astrology. Astrology may be no science; it may even be called a pseudo-science; but that need not mean that books dealing with Astrology can contain nothing valuable. People who wrote these books were not ignoramuses; they fortunately or unfortunately have dealt with many things which, though in their minds, allied to Astrology, have not much direct connection with it. This is what has happened to Meteorology. Our old astronomers believed in the influence of Planets over our Earth; and it is this general belief that led them to mix up Astrology with

many other subjects connected with it only remotely. And as I shall attempt to show, I have found by actual observation that the position of the Sun at any rate does exert a distinct influence upon atmospheric conditions. A brief analysis of what our writers have said regarding Meteorology will also show that they believed,—and this belief rested upon actual observation,—in the influence of the Moon also.

This science is very ancient. The earliest record that we have found is in Bṛhatsamhitā, the encyclopedic work of the 'gem' Varāhamihira, generally believed to have lived in the fifth century A.D. But he refers to, and sometimes quotes from, a number of Ṛṣis, whom even sceptical modern chronology connects with pre-Christian times,—Garga, Parāshara, Kāshyapa and so forth. To a much later period belongs another work named *Vanamālā*, which deals entirely with the subject of Rainfall. Later on again, we have a large number of proverbs current amongst us, which are apparently based on direct observation,—may be, on insufficient data. But the observation and the deductions are there, showing that the science has been a living one.

The story connected with the origin of the proverbs is interesting, and is curiously enough connected with the great astronomer Varāhamihira referred to above. It is said that the great astronomer, away on a distant pilgrimage, suddenly discovered that a certain day and time, a few days forward, were so auspicious that a child born then would turn out to be the greatest astrologer and astronomer. Anxious to secure such a child for himself, he left for home; but unluckily he could not reach home in time; he had to pass the auspicious day in a village, still far off from his home. He managed however to get himself married to the girl of a shepherd on the same day and from her obtained a child who, though he could not be educated in the

proper fashion of a Brahmaṇa, turned out by intuition to be a great astrologer; and the meteorological proverbs that have come to us are believed to have been his sayings.

Many of these proverbs have been collected by John Christian in his 'Bihar Proverbs' (Trubner's Oriental Series) and by Sir George Grierson in his 'Bihar Peasant Life.'

We know that during the year the Sun passes along the ecliptic through its twelve divisions, called the 'twelve signs of the zodiac.' Each of these signs has been roughly divided into 27 'asterisms,' also called 'lunar mansions'. During our rainy season,—*i.e.*, from May to October—the Sun passes through twelve of these 'asterisms',—

(1) Rohiṇī	(2) Mṛgashiras
(3) Ārdrā	(4) Punarvasū,
(5) Puṣya	(6) Aṣhlēṣa
(7) Maghā	(8) Pūrvaphalgunī
(9) Uttaraphalgunī	(10) Hasta
(11) Chitrā	(12) Svātī

The day on which the Sun passes from one asterism into another is marked in our almanacs. I have been marking the atmospheric conditions on these days, and have invariably found that near about the day so marked there is a marked change. I say 'near about' because our almanacs are not so accurate as the more scientifically compiled Nautical Almanac. My observation extends only thus far; and I feel justified in deducing the conclusion that the position of the Sun in relation to the asterisms has a marked influence upon our atmospheric conditions. I have not followed up the subject of forecasting what the actual change will be. This is a matter on which we have elaborate directions regarding observations extending over nearly the whole year. We are taught, for instance, that the atmospheric conditions obtaining during the

month of November or December are indications of the conditions that will obtain 195 days later. There need be nothing unscientific in this; if the atmospheric conditions in the island of Sychelles can be indicative of rain in the Gangetic plain, to come after some weeks, there need be nothing crude about the notion of future rainfall being indicated by conditions appearing six months earlier, especially when we note that the observation should not rest here; it has to extend over the entire period of these 195 days; and the indications of November may be upset by those appearing later on.

We shall now proceed to see what our authors have got to say on this subject.

For the purpose of finding out what amount of rain we shall have during the season known as the 'rains', one has to take note of atmospheric conditions, six months earlier. In the graphic language of our poet-philosophers, the clouds become 'pregnant' during the autumn-winter and 'give birth' to rain six months later. As for the days during which 'conception' takes place, there is a slight difference of opinion. According to some (Siddhasena and his followers), says Varāhamihira, 'conception' takes place after the bright fortnight of the month of Kārtika (Oct.-Nov.); but according to Garga (Vashiṣṭha, Parāshara, Ṛsiputra and Kāshyapa), the symptoms of the 'conception' of the clouds should be observed during the days of the bright fortnight of the month of Mārgashīrsa (Nov.-Dec.),—beginning with that day on which the moon may be in the asterism of Pūrvāṣāḍhā.

Note—The names of the months may be roughly rendered as follows:—

Kārtika	=October—November	*Vaishākha*	=April—May
Mārga	=November—December.	*Jyeṣṭha*	=May—June
		Aṣādha	=June—July
Pauṣa	=December—January	*Shrāvana*	=July—August
Māgha	=January—February	*Bhādra*	=August—September.
Phālguna	=February—March	*Āshvihna*	=September—October.
Chaitra	=March—April		

The 'delivery'—*i. e.* 'birth of the rain'—takes place after 195 days. The rain having been 'conceived' on a certain day during November-December, when the moon has been in conjunction with a certain asterism, it will be 'born' after 195 days (six months and a half), on that day when the moon again comes into conjunction with that same asterism.

If the 'conception' has occurred during the brighter fortnight, the 'delivery' takes place during the darker fortnight,—after 195 days;—if the former has occurred during the night, the latter comes during the day;—and if the former has happened at sunrise or at sunset, the later comes at sunset or sunrise respectively and 'conception' on the moon-less day leads to 'delivery' on the full-moon day. But if the 'conception' takes place during the brighter fortnight of the month of either Mārga or Pauṣa, the resultant rain is small.

Atmospheric 'conception' during	Is indicative of rainfall during
Pauṣa (second half)	Shrāvaṇa (first half)
Māgha (first half)	Shrāvaṇa (second half)
Magha (second half)	Bhādra (first half)
Phālguna (first half)	Bhādra (second half)
Phālguna (second half)	Āshvina (first half)
Chaitra (first half)	Āshvina (second half)
Chaitra (second half)	Kārtika (first half)

The same opinion has been held also by Garga and Parāshara; the later holding that 'conception' during the day brings rain during the night and *vice versa.*

If at the time of 'conception', clouds have appeared in the East, then at the time of 'birth'—*i. e.* actual rain,—they will appear in the West; and so on with the other quarters. Similarly, if at the time of 'conception', the wind has blown from the East, then at the time of rain, it will blow from the opposite quarter.

SIGNS OF 'CONCEPTION'

Atmospheric conditions indicative of future rainfall.

(1) Pleasant wind, (2) soft wind, (3) northerly wind, (4) north-easterly wind, (5) easterly wind, (6) clear sky, (7) soft, white and deep halo round the moon or the sun, (8) sky overcast with extensive, deep and soft clouds, (9) needle-shaped clouds, (10) razor-shaped clouds, (11) blood-red clouds, (12) dark-coloured sky, (13) blue-coloured sky, (14) bright moon, (15) bright stars, (16) rain-bow in the morning or in the evening, (17) thunder, (18) lightning, (19) appearance of a second sun, (20) sweet and peaceful sounds emanating from birds and wild animals, from the North on the North-East or the East; (21) Planets shining in the full form and with soft light, (22) trees with roots growing freely, (23) men and cattle appearing happy.

These are the signs generally indicative of future rainfall.

The observer has been directed by Parāshara to take observations, during the four months beginning with Māgha, of all phenomena relating to Rainbows, Clouds, Lightning and Thunder. These phenomena are indicative of the quantity of rainfall during the succeeding rainy months.

The details of these observations have been described by Varāhamihira (21-19 et seq):—The following are signs indicative of good rainfall:—

During the months of Mārga and Pauṣa (November-January)—Red sky in the morning and in the evening; clouds with solar and lunar halos; and less than usual cold.

During the month of January-February:—High winds; Frost and Mist obscuring the light of the Sun and of the Moon; Sun's rays cool like ice; dim moonlight; excessive cold; sunrise and sunset under clouds.

During the month of February-March,—Dry high

winds; appearance of clouds; soft but broken halos round the Sun and the Moon; tawny colour of the Sun; copper colour of the Sun.

During the month of March-April—winds, clouds, rain, halos.

During the month of April-May—halos accompanied by clouds, winds, rain, and thunder.

During the months of 'conception' (November—May)—if the clouds that appear are of the colour of either silver or pearl or the Tamāla-leaf or the blue lotus or soot or aquatic animals,—then the resultant rain during the season is profuse. If the clouds are heated by the rays of the Sun, or accompanied by slight winds,—then the rain that follows after 195 days is too excessive.

The following are the phenomena that tend to nullify the chances of rain indicated by the phenomena described above:—(1) Fall of meteors, (2) Lightning, (3) Shower of dust, (4) Burning of the quarters, (5) Earth-quake, (6) Appearance of palaces in the clouds, (7) Comets, (8) Impact of Planets, (9) Signs of blood, flesh, fat, butter or oil in the rain-water, (10) Rainbow, (11) Eclipse, (12) Thunder without clouds and (13) Hails.

It is explained that if any of these phenomena appear after the appearance of the phenomena that have been described as indicative of rain, they are to be regarded as nullifying those indications, and thereby reducing the possibility of rainfall.

Further, if, during the months of 'conception', the phenomena appearing are found to be contrary to those described as indicative of rain,—then the chances of rainfall would be small.

Among conditions improving the chances of rain is the appearance of "conception" on certain days on which the moon happens to be in a particular asterism. These

asterisms have been enumerated by Varāhamihira in 21. 28 et. seq.

If 'conception' takes place under the above favourable conditions during the month of November-December, then after 195 days, there is good rain for 8 days; if during December-January, there is rain after 195 days, for 5 days; if during January-February, for 16 days; if during February-March, for 24 days; if during March-April, for 20 days; if during April-May, for 3 days. (Varāhamihira 21.30)

If 'conception' is due to all the five conditions—of wind, rain, lightning, thunder and clouds,—then the resultant rain falls over an area of 400 square miles; if one of the five conditions has been absent, it extends over 200 square miles; if two conditions have been absent, then over 100 square miles; if three have been absent, over 50 square miles; if four have been absent, over 20 square miles. (31).

We had also rain-gauging in the past. If the 'conception' has been due to all five conditions, then the quantity of resultant rain is one '*droṇa*'; if it has been due to wind alone, the resultant rain is 3 '*āḍhakas*'; if it has been due to lightning, the rain is 6 '*āḍhakas*'; if it has been due to clouds, the rain is 9 '*āḍhakas*'; if it has been due to thunder, the rain is 12 '*āḍhakas*' (32).

These measures of rain—'*droṇa*' and '*āḍhaka*'—have been thus described by Parāshara:—When the rainfall fills to the brim a vessel 20 anguls (inches) square and 8 anguls deep, the quantity of rain is to be regarded as an '*āḍhaka*'; and four such '*āḍhakas*' constitute a '*droṇa*'.

Varāhamihira's own measure is given under 23.2:—

A vessel with a circumference of 1 'hasta' (24 anguls) and 1 hasta deep should be placed outside; if it becomes filled with the rain-water, it means that we have had one *āḍhaka* of rain; and 4 such *āḍhakas* go to make up a *droṇa*.

If the 'conception' occurs when 'evil' planets are in the ascendant, then the resultant rain is accompanied by hail, lightning and fish ; if, on the other hand, the planets in the ascendant happen to be 'benign', it brings profuse rain.

If there is rain at the time of 'conception', that conception becomes abortive (34).

During the month of May-June, on the first four days of the brighter fortnight, if we have soft and easy winds blowing, the 'conception' that has taken place during the winter becomes further developed ; so also, if on these same days, the sky is over-cast with soft and dense clouds. (22.1).

During the month of May-June, if any rain falls upon the day on which the moon is in the asterism of Svātī, then there would be no rain during the month of July-August ; if it falls on that day on which the moon is in the asterism of Vishākhā, then we shall have a rainless month of August-September ;—if it falls on the days on which the moon is in the asterism of Anurādhā, we shall have a rainless month of September-October.

If, on the said four days of May-June, there is lightning with slight showers, or with dust-storm, or if the sun and moon are overclouded, it is a good sign. Similarly, if birds sing sweetly, or children play happily, or the sun and the moon are surrounded by a halo, or there are dense clouds,—all these are favourable signs.

During the month of June-July, (a) if it rains on the day on which the moon is in the asterism of either Hasta, or Pūrvāṣāḍhā, or Mṛgashiras or Chitrā or Rēvatī or Dhaniṣṭhā,—then on the corresponding days during the next lunar month, there should be 16 *droṇas* of rainfall ;—(b) if it rains on those days when the moon is in the asterism of (8) either Shravaṇā or Maghā or Anurādhā or Bharaṇī or Mūla,—on the corresponding days next

month, there should be 14 *droṇas* of rainfall;—if, during the moon's residence in the asterism of either Shatabhiṣak or Jyēṣṭhā or Svātī,—then on the corresponding days the rainfall should be 4 *droṇas*;—if, during the moon's residence in the asterism of. Kṛttikā, 10 *droṇas*;—if during the moon's residence in Pūrvaphālguni, 25 *droṇas*;—in Punarvasū, 20 *droṇas*;—in Vishākhā or Uttārāsāḍhā, 20 *droṇas*;—in Ashleṣā, 13 *droṇas*;—in Uttara-bhādra or Uttara-phālguni or Rohiṇī, 25 *droṇas*;—in Purva-bhādra or Pūsya, 15 *droṇas*;—in Ashvinī, 12 *droṇas*; in Ārdrā, 18 *droṇas*.

In Chapters XXVI and XXVII there are described certain indications of rain to be observed on one particular day, the full-moon day of the month June-July:—

If the wind blows from the East or the North-East and is fragrant and agreeable to the touch, it indicates good rain and good crops. If it is from the South-East, South-West, or North-West, the crops would be neither good nor bad. If the evening sky on that day is of the colour of emerald, or silver, or honey, or gold, and if there appear in the sky clouds of the shape of a tree, this indicates good rain. If at sunest, the wind blows from the North-East, it indicates good crops. If it blows from the East, whirling like sea-waves, it indicates excellent winter and spring crops. If there is continuous hot wind from the South-East, it indicates that everything on the earth will be reduced to ashes. If the wind at sunset blows from the South and is high, accompanied by dense clouds, it indicates rain. If at sunset the wind blows from the South-West, high and continuous, it indicates terrible famine. If at sunset the wind blows from the West, it indicates good crops, but also war. If the wind blows from the North-West, it indicates profuse rain and excellent crops. If it blows from either West or North, it indicates good rain.

In Chapter XXVIII we have certain signs described, which are indicative of immediate rain. During the rainy season, if the sun at the time of rising is exceptionally bright, or if the taste of water is insipid, or the colour of the sky is that of the cow's eye, if salt begins to sweat, if fish in tanks begin to frisk towards land, if cats frequently scratch the ground, if metal vessels emit a fishy smell, if ants with their eggs move from one place to another, or if serpents are seen to ascend trees, all these signs are indicative of immediate rain.

The above is based mainly upon a study of Varāhamihira's encyclopedic work, the Bṛhatsaṃhitā, which is believed to have been written in the fifth century A.D. It will serve to show how closely the atmospheric conditions were observed and noted, with a view to ascertain, to almost a nicety, the amount of rainfall expected during the year. There are other works dealing with the subject; three or four of them have been referred to and quoted by Bhaṭṭotpala, in his commentary on the Bṛhatsaṃhitā. It promises to be an interesting field of research; and it is hoped younger scholars may be attracted to it, and let us have the results of their study, which, one feels sure, will go to show that our astrologers—at least of the ancient times,—were not so steeped in superstition or unscientific in their methods as they have been supposed to be.

DEPARTMENT OF ENGLISH

[*Note.*—Though the subject-matter of the paper is related to the Department of *Sanskrit*, yet, it has been included under the activities of the Department of *English*, as the writer is a member of the latter Department.]

A CONTEMPORARY LIFE OF AKBAR IN SANSKRIT.

A PRELIMINARY NOTE

AMARANATHA JHA, M.A., Reader in English.

On December 3, 1833, in the Mackenzie Collection, a manuscript described as "Sarvadeshavrittāntasaṅgraha" or "Akbar Nama" was acquired for the India Office Library. It remained practically unknown till in an obscure corner of his remarkable biography of Akbar, the late Mr. Vincent Smith mentioned it. Thanks to the munificence of the Hon'ble the Maharajadhiraj of Darbhanga and the courtesy of my esteemed friend, Dr. F. W. Thomas of the India Office Library, a photograph of the manuscript is before me. In the present paper I shall give a brief account of this manuscript. It is clearly not written by the author as there are copious errors of transcription, and the character is Devanagari. The original manuscript would almost certainly have been in the Maithili character.

It begins thus. (I am reproducing the original exactly as it is; the corrected version and suggestions must wait):

श्रीगणेश ॥ यद्वक्तृ (?) तत्वस्वीकृद्भिरतिसूक्ष्मत्वगामिभिः ।
स्वच्छान्तःकरणैः प्रातस्स वाग्भिः सूक्ष्मदर्शिभिः ॥४॥
जगन्निर्मितरेखाया धीश्चित्रैकर्कटार्पकैः ।
महाभौतिकसृष्टयन्तर्दृश्यं यत्पार्थिवं वपुः ॥५॥
तत्रैवाति महामूल्यं सुवर्णरजतादिकम् ।
अत्युत्कृष्टस्वभावाद्यं हीरकादिमहाधनम् ॥६॥
मूल्यप्रतिकृतौ यत्तु तमात्यन्तमितेर्भवत् (?)
न शक्यमुत्तोऊयितुं मानपात्रात्मयाचियत् ॥७॥

And so on for ten tiresome pages of more or less obscure verses. On Page 11a we have the following:

"वार्त्ताप्राप्तिसंदेशः कार्य्यशक्तिकर्णे निपपात । यत् अर्थशालाचित्रकरनत्वं ग्रन्थप्रथनं करोषि येन ग्रन्थादिभागं स्तुत्याऽलंकुर्याः किन्तु सकलदेशकालयोरखिलजनैरनतशिरोभिः शिरसि विहितनिदेशस्य निखिलसुरत्राणमुकुटमणेश्चरितानि लिखसि ॥"

At the bottom of 13a occurs this:

"अथ वंशावली लिख्यते । एतस्य हजरतिशाहनशाहीकस्य पूर्वजाः सर्वेऽपि सम्राजो बभूवुः । ।श्रीअबुलमुजफ्फर जल्लालदी मुहम्मद अकबर पातिशाहः । स नसीरुद्दी मुहम्मद हुमायूं पातिशाहात् स जहीरुद्दीं मुहम्मद बाबुर पातिशाहात् । स उमरशयेखमिर्जातः । स सुलतां अबूसआदमिर्जातः । स सुलतां मुहम्मदमिर्जातः । स मीराशाहात् । स साहिब किरां अमीरतिमुरकुरगांतः । स अमीरतरागायितः । स अमीरबरबुलात् । स अलंगिरबहादुरतः । स इचिलनोयांतः । स कराचारचोयांतः । स सेागोहेजनतः । स इरदामजीवरलासतः । स काचोलीबहादुरतः । स तोमिनहखांतः । स वायुसंगुरखांतः । स कायदूंखांतः । स जूमिननखांतः स बूकाका श्रां तः । स बूजंअजरका श्रांतः ।"

and for thirty generations more Akbar's ancestry is traced, until the biographer mentions Adam, and there he stops. Then he discusses the time that, according to various beliefs, has elapsed since creation.

On Page 14a an anecdote is described thus:

एतेषां च तेजोविशेषं दृष्ट्वा मनसि भूयसीमसहिष्णुतामासादयत् । एतेषामपचयार्थं स यं यं व्यापारं कृतवांस्तेनैव व्यापारेण परमेश्वरेच्छावशादेतेषामुत्कर्ष एवाभवत् । तद्यथा । कदाचिन्मिर्जा कामरां परमोत्सवभूतायां कस्यांचिद्रात्रौ स्वपुत्रं शाहनिशाहीकांश्च प्रत्यवदत् । यदनयोर्बालकयोर्मध्ये यो मल्लयुद्धे जेष्यति तस्मै अयं विचित्रो दुन्दुभिर्दातव्य इति । श्रुत्वा चैतत् शाहनिशाहीकै कामरां पुत्रो मिर्जाइबराहिम नामावैज्यैज्ष्ठोऽपि परमेश्वरदत्तमाहात्म्युतया निमातितः । स्वबाहुबलेन दुन्दुभिं गृहीत्वा स्वयं दुन्दुभिनिनादं चक्रुः ।"

That is followed by an account of Babur, who is referred to as फ़िरदौसमकानी and of Humayun who is described as जन्नताशयानी—a curious blend of languages.

The manuscript runs up to about 250 pages, but is incomplete. Its value historically cannot be determined

until it is more carefully examined and compared with the Ayeen-i-Akbari; but its literary interest is certainly great. The author of it is the famous Mahesha Ṭhakkura, the well-known writer and commentator on Nyāya who obtained from Emperor Akbar the grant of the territory included under the present 'Darbhanga Raj.' It is almost unique as a mediæval biography on such a large scale; the efforts at accuracy are obvious, and it should be of interest to consider what new information the book supplies or what fresh light it throws on the period it deals with. The following may be quoted as a specimen of the style in which the work is written:

"एते काबुलदुर्गस्य संरक्षणं सम्यक्तया कुर्वन्ति स्म । ततश्चेमां वार्तां श्रुत्वैव फिरदौसमकान्यो निजभ्रातुः किञ्चिदसुस्थस्य जहांगीरमिर्जाकस्य पार्श्वे सर्वं कटकं संस्थाप्य परिमितैरेव जनैस्समं कथं कथमपि हिमपूर्णं हिन्दूकोहनामकं पर्वतमतीत्य प्रहण्वशेषापारजन्यां काबुलनगरं प्राप्नुवन्तः ।"

The manuscript comes to an end with these words:

"इति श्रीमहामहोपाध्याय श्रीमहेशठक्कुरविरचिते सर्वदेशवृत्तान्तसंग्रहः पकाश । शुभमस्तु । मङ्गलमस्तु ।"

I hope, before very long, to edit this manuscript with an introduction, translation and copious notes.

DEPARTMENT OF SANSKRIT

THE MĀNASĀRA AND VITRUVIUS *

P. K. ACHARYA, M. A., Ph.D., D. Lit., I. E. S..

Professor of Sanskrit.

The name Mānasāra is of ambiguous significance. The treatise bearing this name is the standard *Vāstu-Śāstra*. The identity of its author or the date of its composition is yet unsettled. It deals in a systematic manner with architecture. In the *Vāstu-Śāstra* the term architecture is taken in its broadest sense and implies what is built or constructed. Thus in the first place it connotes all kinds of buildings: religious, residential, and military; and their auxiliary members and component mouldings. Secondly, it implies the town-planning; laying out gardens; constructing market-places including ports and harbours; making roads, bridges, gate-ways, triumphal arches; digging wells, tanks, trenches, drains, sewers, moats; building enclosure walls, embankments, dams, railings, landing-places, flight of steps for hills and bathing ghāts, and ladders. Thirdly, it denotes articles of furniture such as bedsteads, couches, tables, chairs, thrones, wardrobes, baskets, cages, nests, mills, conveyances, lamps, and lamp-posts for the streets. It also includes the making of dresses and ornaments such as chains, and crowns and

*This is a chapter of a book named Śilpa-Śāstra which is in course of publication in the Government Press.

1. Etymologically the term *Mānasāra* implies 'the essence of measurement'—*sāra* meaning 'essence' and *māna* 'measurement.' In the treatise itself the term is used in different senses, namely, a generic name for the professors of architecture, a personal name of an architect, and the title of a treatise. In the *Dasā-Kumāra-Charita* of Daṇḍin Mānasāra is the name of the king of Malwa.

For further details see Preface to the first edition of the Mānasāra by the present writer.

head-gears and foot and arm wears. Architecture also includes sculpture and deals with carving of phali, idols of deities, statues of great personages, images of animals and birds. As preliminary matters it is also concerned with the selection of site, testing of soil, planning, designing, finding out cardinal points by means of a gnomon, dialing, and astronomical and astrological calculation.

In 1834 in his essay on the architecture of the Hindus Rām Rāz referred to the first few chapters of the Mānasāra from a single fragmentary manuscript he had access to. Since then several manuscripts have been discovered but owing to some great difficulties set forth elsewhere no body had made any attempt to deal with this huge text in any way for a period of 80 years when the present writer undertook the work in 1914. The text, as known from the eleven badly preserved manuscripts on which the first edition of the present writer is based, is written in five different scripts[1], has undergone five recensions and comprises more than 10,000 lines of a language rightly branded by Dr. Bühler (and Sir R. G. Bhandarkar) as "barbarous Sanskrit."[2] Sketches or illustrations of any kind are absolutely wanting in all the available manuscripts. There are, besides, no commentaries on the texts, nor could any body make an attempt to translate any of the texts into English before the translation of the Mānasāra into English by the present writer, mainly because there had been no dictionaries, before the compilation of the Dictionary of Śilpa-Śāstras by the present writer, dealing with the architectural terms which necessarily abound in the Mānsāra and other texts on architecture.

Vitruvius is the name of a Roman architect. His treatise is the standard work on European architecture.

1. Grantha, Tamil, Telugu, Malayalam and Nāgari.
2. Epigraphia Indica Vol. I. p. 377.
Indian Antiquary Vol. XII. pp. 140, 141.

"Among the ancient authors he is merely mentioned by Pliny as one of those writers from whom he compiled; and by Frontinus, in his treatise on Aqueducts, as the first who introduced the Quinarian measure."

His treatise seems to have been composed twenty-five years before the Christian era. The title of this treatise is lost, if it originally had one. The Editio princeps printed at Rome in or about 1486 bears no title. The unique position of this treatise is, however, sufficiently clear from the fact that since its first appearance in the fifteenth century there have been till 1807 forty-two editions of the work practically in all the European languages. There are seventeen editions in Latin, eleven in Italian, two in Spanish, six in French, four in German and two in English. [1]

The treatise is divided into ten books which do not bear any titles. Each book contains a number of chapters

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1. See Gwilt Encyclopedia of architecture, XV—XXV, for fuller details of the following:—

Latin editions.—

1486—Editio princeps printed at Rome by George Herolt begins without a title—sulptius lectori salutem. Polenus says "there are but few errors in this edition."

1496—Printed at Florence, according to Fabricus, the orthography of this edition is more correct than the preceding one.

1497—The name of the editor does not appear. With a few slight variations this is little more than a reprint of the Florence edition. In this the chapters of the first book are differently divided from those of the two former editions.

1511—This is the first illustrated edition. It contains many wood-blocks and figures. Jocundus (the editor) altered the text of the two former editions in many places.

1513—The figures in this edition are the same as the preceding, but considerably reduced and more imperfectly kept.

1522—This is a reprint of the preceding edition with the same blocks for the figures.

varying from seven to twenty-two. The chapters also have not got any proper titles. The treatise deals with both the civil and military architecture. The rules respecting military engines, "now incomprehensible, but doubtless in his time sufficiently clear," are laid down in the last book. The

1523—This was probably edited by Will Hayon of Lyons. This is counter of the Giunta edition. Some of its figures are taken from the first Italian edition of 1521 which is noticed herein after.

1543 - The text is nearly the same as that of Jocundus. The figures of the wood-blocks are partly borrowed from the Giunta edition and partly from the Italian edition of 1521.

1550—The text is the same as that of the 1543 edition. But it contains notes of Philander which were first published at Rome in 1544.

1552—" Philander himself superintended this edition, chiefly following the Giunta text, which he collated with several MSS. The wood-blocks are better than any preceding edition."

1567—Barbaro in this seems to have mostly followed Philander's edition of 1552.

1586—"Harwood says that the editor of this edition was Jo, Tornaesius junior, and that it is more correct, though less elegant than that produced by the father in 1552."

1649—With commentary of Meibomius on those chapters relating to musical notation. This was the best edition of the author produced at that time. " De Laet professes to follow the text of Philander's edition, but neither was this accurately done, nor were the notes of Philander, nor the Lexicon of Baldus given entire, as the title would import."

1758—By Marchese Berardo Galiani at Naples with an Italian version noticed under the Italian editions. Harwood says this is "a fair and valuable edition."

1800—The text of this edition is of little value. Nor its plates well executed. It has no notes appended but it contains the glossary in five languages.

civil architecture comprises both temples and residential buildings. "That he should have met with opposition from his brethren is quite consonent with later experience, for the rabble of ignorant builders, and artisans, and draftsmen are of the same class as those that flourished subsequently to Vitruvius." From this remark of Gwilt it appears that Vitruvius was induced to "write his treatise with a view to assisting the uneducated professional architects" who like those of India depended solely on the knowledge handed down to them from their equally uneducated forefathers.

'Certain points of similarity between the Mānasāra and the treatise of Vitruvius are so striking as to raise the presumption that the two works are in some way dependent on each other.' This thesis is proposed to be illustrated in this article.

Practically seven-tenths of both the works are avowedly architectural:

1807—It contains notes.

1807—In the same year another edition was published. The second and third volumes are devoted to commentaries on the text. It contains, however, no plates. "This is the best edition of the author which has appeared."

Italian editions—

1521—This is one of the earliest and rare versions of Vitruvius. It was translated with the assistance of Benedict Jovius by Gaesar Caesarianus who was one of the architects of the Cathedral of Milan. One of the plates contains a plan and two sections of this Cathedral.

1524—This is a repetition of the preceding edition but without the notes of Caesar Baesarianus.

1535—This is copied from the preceding edition, but the index is not quite so copious.

1536—A translation of the first five Books. Perugia.

1556—With Barbaro's commentary.

Out of seventy chapters of the Mānasāra the first fifty deal with architecture proper, and out of ten books of Vitruvius, the first seven deal with the same subject.

The remaining twenty chapters of the former are devoted to sculpture and the remaining three books of the latter deal mostly with war instruments, machines,

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1567—With Barbors's commentary.

1584—"Similar to the preceding edition."

1629—"Very similar to the preceding edition."

1641—Little differing from the preceding.

1758—In Napoli, accompanied with the Latin text.

1790—Another edition by Galiani, similar to the preceding but without the Latin text.

Spanish editions—

1602—Without plates.

1787—Large folio with plates.

French editions—

1547—First version in French, Jan Martin, Paris.

1572—A reprint of the preceding, Cavellat, Paris.

1618—Printed from the two preceding editions by Gean de Tournes at Geneva.

1673—Translated by Perrault. Figures are numerous and well executed.

1684—With plates, best Perrault's editions.

1816—With plates. Bruxelles.

German editions—

1548—With plates on wooden blocks cut by Frard Schoen.

1575—A repetition of the preceding Basil.

1614—Another repetition with a little different title.

1796—With a life of Vitruvius in the first volume. This edition contains many illustrations of the author.

English editions—

1771—Translated from original Latin by Newton, London.

1791—Second volume with many plates.

It exhibits defective knowledge of Latin ; but notes are good.

Latterly a portion was translated by Wilkins.

After Joseph Gwilt's translation there have been several other editions in English.

and engines. Of the similar seven-tenths in both the works, names of many chapters and the contents too in most instances are the same.

The Mānasāra opens, following the usual custom, with a prayer to the Creator Brahmā and touches upon the origin and development of the science of architecture, from Śiva, Brahmā, Vishṇu through Indra, Brihaspati, Nārada to the class of Ṛishis called Mānasāra, and concludes the introduction with a list of the chapters.

Vitruvius, too, opens with a prayer, to his patron, Cæsar, and acknowledging his obligations to Cæsar's father and sister, concludes with a proposal to give an account of the magnificent edifices Cæsar had built and to develop all the principles of the art.

The next chapter (II) in the Mānasāra deals with two distinct subjects, the system of measurement (*mānopakaraṇa*) and the requisite qualifications of an architect (*Śilpi-lakshaṇa.*)

The corresponding chapter is marked I instead of II by Vitruvius, because the preceding chapter goes without any numbering as it is called introduction. This present chapter deals exactly like the corresponding chapter in the Mānasāra with two distinct subjects under the heads, "what architecture is" and "of the education of an architect." The former of these two subjects has again been treated in the chapter following, namely, III, of the Mānasāra and is noticed below. The striking similarity in the training demanded of the architect by the two authorities may conveniently be compared here.

According to Vitruvius "an architect should be ingenious, and apt in the acquisition of knowledge. He should be a good writer, a skilful draftsman, versed in geometry and optics, expert at figures, acquainted

with history, informed on the principles of natural and moral philosophy, somewhat of a musician, not ignorant of the sciences both of law and physics, nor of the motions, laws, and relations to each other, of the heavenly bodies." The absolute necessity for these qualifications has been very satisfactorily elaborated by Vitruvius.

In the Mānasāra artists are first divided into four classes; they together form the guild of architects, each an expert in his own department but possesses a general knowledge of the science of architecture as a whole. They consist of the chief architect (*sthapati*), the draftsman or the designer (*sūtra-grāhin*), the painter (*vardhaki*) and the joiner (*sūtra-dhāra*).

According to the Mānasāra the chief architect is expected to be well-versed in all the sciences. He must possess a knowledge of all the Vedas and all the Śāstras. He must be proficient in law, mathematics, history, geography, painting, draftsmanship, mechanics, and expert in the ocean of the science of architecture. He must be very learned, meritorious, patient, and dexterous, a champion of large experience, of industrious habit, and of noble descent, full of resources and capable of application to all works. He must possess a wide outlook, bold temperament, and self-control. He must be above committing errors. He must have a good name and be faithful to his employers (lit. friends). He must be endowed with all the qualifications of a supreme managing director. He must not be deformed or have any disease or disability; he must also be free from the seven vices, namely, hunting, gambling, day-dreaming, black-mailing, addiction to women, etc.

A similar set of qualifications has also been demanded of the other three artists; but *sūtragrāhin* is expected to possess expert knowledge of draftsmanship, the *vardhakī* of painting, and the *sūtradhāra* of carpentry.

The utility or the possibility of so many attainments in a single person has not been expressly discussed in the Mānasāra. But Vitruvius has submitted an interesting explanation in conclusion.

It is familiar to every body that for success in any profession in life one must be clever, industrious, honest and generous. It is also easily understood that an architect, who has got to do both manual and brain work, must not be deformed and must be free from all diseases and disability.

According to Vitruvius he is required to be a good writer also, because an architect is to commit to writing his observations and experience, in order to assist his memory. Drawing is employed in representing the forms of his designs. Geometry, which forms a part of mathematics, affords much aid to the architect; to it he owes the use of the right line and circle, the level and the square, whereby his delineations of buildings on plane surfaces are greatly facilitated. Arithmetic estimates the cost, and aids in the measurement of the works; this assisted by the laws of geometry, determines those abstruse questions wherein the different proportions of some parts to others are involved. The science of optics enables him to introduce with judgment the requisite quantity of light according to the aspect. Unless acquainted with history he will be unable to account for the use of many ornaments which he may have occasion to introduce. For history the expression 'purāṇa' is used in the Indian literature and it implies mythology or mythological stories which are as a rule depicted in the buildings of a nation. There are, however, other uses of history for an architect.

"Moral philosophy," says Vitruvius, will teach the architect to be above meanness in his dealings, and to avoid arrogance; and will make him just, compliant and faithful to his employer; and what is of the highest

importance, it will prevent avarice gaining an ascendancy over him; for he should not be occupied with the thoughts of filling his coffers, nor with the desire of grasping everything in the shape of gain, but by the gravity of his manners and a good character, should be careful to preserve his dignity." These precepts of moral philosophy are prescribed by our Indian authorties almost in the same terms. We have seen above that the architect is required to be of noble descent, pious and compassionate. He must not be malicious or spiteful. He must be content and free from greed. He must be truthful and possess self-control. He must be above the seven vices. He must be faithful to his employer. He must not have excessive desire for gain. He must be of good behaviour and generous enough to forgive his rivals.

The doctrine of physics is necessary to him in the solution of various problems; as for instance, in the conduct of water, whose natural force, in its meandering and expansion over flat countries, is often such as to require restraints, which none know to apply but those who are acquainted with the laws of nature. This matter too has been more exhaustively discussed in various chapters of the Mānasāra.

"Music assists him in the use of harmonic and mathematical proportion." In these matters, the Mānasāra is rather too elaborate; in most individual cases, nine proportions have been suggested and the selection of the right proportion and harmony has been made dependent on the application of the six formulæ, which are treated in a very technical manner based on mathematics. According to Vitruvius, music is moreover absolutely necessary in adjusting the force of the balistæ, catapultæ and scorpions in whose frames are holes for the passage of the homotona, which are stained by gut-ropes attached to windlasses

worked by hand-spikes. Unless these ropes are equally extended, which only a nice ear can discover by their sound when struck, the bent arms of the engine do not give an equal impetus when disengaged, and the strings, therefore, not being in equal states of tension, prevent the direct fight of the weapon. A knowledge of music is especially useful to the architect in building theatres, lecture rooms, and such other halls where the spread of sound is taken into particular consideration. Both Vitruvius and Mānasāra are equally enthusiastic in speaking about it. The former, further, says that the architect "would, moreover, be at a loss in constructing hydraulic and other engines if ignorant of music." "Skill in physics enables him to ascertain the salubrity of different tracts of country, and to determine the variation of climates, for the air and water of different situations, being matters of highest importance, no building will be healthy without attention to those points." Most elaborate description on the selection of site and the examination of soil is given in the Mānasāra and other architectural treatises*. The salubrity of the tracts is minutely ascertained with reference to the site where a village, town, fort, palace, temple, or dwelling house is to be built. The soil is examined with regard to its shape, colour, odour, features, taste, and touch. The elevation of the ground as well as the luxuriant growth of certain plants, trees, and grasses on the ground are also minutely examined.

"Law should be an object of his study, especially those parts of it which relate to party-walls, to the free course and discharge of the eaves' waters, the regulations of cess-pools and sewage, and those relating to window

*Brihat Samhitā, Gārga, Viśvak, Kāśyapa, Vāstu-ratnāvali, Vasishtha Samhitā, Vāstupradīpa, Nārada, Griha-kārikā, Bhṛigu, Ś́ilpa-dīpaka, Bhavishya Purāṇa. (See quotations from these works in the writer's dictionary of the Ś́ilpa Ś́āstra.)

rights. The laws of sewage require his particular attention, so that he may prevent the employers being involved in law-suits when the building is finished. Contracts, also, for the execution of the works, should be drawn up with care and precision, because, when without legal flaws, neither party will be able to take advantage of the other."

Law as explained by Vitruvius is not mentioned in the list, in so many words, of accomplishments given in the Vāstu-śāstras quoted above. But most elaborate instructions are given in the Arthaśāstra and other treatises on the party-walls, sewage system, windows and other openings.*

"Astronomy instructs him in the points of the heavens, the laws of the celestial bodies, the equinoxes, solstices, and courses of the stars; all of which should be well understood in the construction and proportions of clocks." In the Vāstu-śāstras dialing is an important subject; but astronomy, which is always mixed up with astrology, has been drawn upon particularly with regard to the auspicious moment invariably observed in almost all matters.

Vitruvius has added an explanatory note on the expression, 'all sciences', of which the architect is required to have sufficient knowledge. This explanation will indeed throw a clear light upon a similar expression, 'Sarva-Śāstra,' used by the Indian authorities. But for the following note of Vitruvius, we would have taken the term Sarva-Śāstra as an exaggeration which is very often found in the Sanskrit literature to imply nothing more than general knowledge.

"Perhaps, to the uninformed mind," begins Vitruvius, "it may appear unaccountable that a man should be

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*See quotations under Bhū-parikshā in the writer's dictionary.

able to retain in his memory such a variety of learning; but the close alliance with each other, of the different branches of science, will explain the difficulty. For as a body is composed of various concordant members, so does the whole circle of learning consist in one harmonious system." 'On this account, Pythius, the architect of the noble temple of Minerva at Priene, says, in his commentaries, that an architect, should have that perfect knowledge of each art and science which is not even acquired by the professors of any one in particular.' This seemed rather too much to Vitruvius; so he asks, "how can it be expected that an architect should equal Aristarchus as a grammarian, yet should he not (sic) be ignorant of grammar. In music, though it be evident he need not equal Aristoxenus, yet he should know something of it. Though he need not exceed, as Apelles, in painting, nor as Myron or Polycletus, in sculpture, yet he should have attained some proficiency in these arts."

"Thus also, in other sciences," concludes Vitruvius, "it is not important that pre-eminence in each be gained, but he must not, however, be ignorant of the general principles of each. For in such a variety of matters, it cannot be supposed that the same person can arrive at excellence in each, since to be aware of their several niceties and bearings, cannot fall within his power.........Wherefore Pythius seems to have been in error, forgetting that art consists in practice and theory. Theory is common to, and may be known by all, but the result of practice occurs to the artist in his own art only. The physician and musician are each obliged to have some regard to the beating of the pulse, and the motion of the feet, but who would apply to the latter to heal a wound or cure a malady? So, without the aid of the former, the musician affects the ears of his audience by modulations upon his instrument. The

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astronomer and musician delight in similar proportions, for the positions of the stars, which are quartile and trine, answer to a fourth and fifth in harmony...." Throughout the whole range of art, there are many incidents common to all. Practice alone can lead to excellence in any one. That architect, therefore, is sufficiently educated, whose general knowledge enables him to give his opinion on any branch when required to do so. Those unto whom nature has been so bountiful that they are at once geometricians, astronomers, musicians, and skilled in many other arts go beyond what is required of the architect.

No more observations are perhaps necessary with a view to reasserting the striking similarities between the Mānasāra and Vitruvius on this point. This series of similarities between the injunctions of the two standard works on such an important matter as the training of the architect, the very soul of architecture, seems to have been due to something more than mere accident.

The next chapter (III) in the Mānasāra, called *Vāstu-prakaraṇa* defines *vāstu* or habitation and divides it into four classes, ground, building, conveyance and couch (*dharā*, *harma*, *yāna*, and *paryṅka*).

Chapter (IV) called, *Bhūmi-parīkshā*, examination of soil, deals with the site where a village, town, fort, palace, temple, or dwelling is to be built and examines the soil thereof with regard to shape, colour, odour, features, taste, touch; the elevation of the ground; and the luxuriant growth of certain plants, trees, and grasses.

Chapter (V) called *Bhūmi-saṃgraha*, selection of site, deals further with the soil before it is finally selected for a building site.

The next chapter (VI) considers the orientation of buildings, and recommends that the building should preferably face the east or north-east, and never the south-east.

Reasons have not been discussed fully beyond stating that this is auspicious or that is inauspicious. Incidentally, the principles, mechanics, and details of dialing have been exhaustively discussed.

The following chapter (VII) discusses the design or divisions of the selected site for a village, town, or house, into a number of plots. Thirty-two schemes are distinguished, each of which is divided into squares of various numbers.

Following the usual custom this introductory section concludes with a chapter (VIII) on offerings to various deities. In this matter too the chief architect takes a leading part.

The corresponding chapter (II) of Vitruvius is called "of those things on which architecture depends." It deals with the fitness (ordination) and arrangement (disposition) also proportion, uniformity, consistency, and economy and is divisible into three heads ichonography, orthography, and scenography which considered together constitute design.

The next chapter (III) is called "the different branches (building, dialing, and mechanics) of architecture," and the chapter following (IV) is named "the choice of healthy situation" which deals with climatic condition and elevation of the building site as well as with its aspects or orientation. Unlike the Mānasāra the consideration of fogs, rains, heat, and cold, which are peculiarities of the European countries, has been given prominence to. The explanations of aspects recommended are satisfactory. "A city on the sea-side," it is stated, "exposed to the south or west will be insalubrious; for in summer mornings, a city thus placed would be hot, at noon it would be scorched. A city also with a western aspect would even at sunrise be warm, at noon hot, and in the evening of a burning temperature. Hence the constitution of the inhabitants of such places, from such continual and

excessive changes of the air, would be much vitiated," (page 14). After citing opinions of physicians and others and supporting by illustrations, it is further stated "When, therefore, a city is built in a marshy situation near the sea coast, with a northern, north-eastern, or eastern aspect, on a marsh whose level is higher than the shore of the sea, the site is not altogether improper; for by means of sewers the waters may be discharged into the sea: and at those times, when violently agitated by storms, the sea swells and runs up the sewers, it mixes with the water of the marsh and prevents the generation of marshy insects; it also soon destroyes such as are passing from the higher level, by the saltness of its water to which they are unaccustomed." The frequent mention of sea-side, it is needless to point out, is due to the situation of the prominent Italian cities on the sea-shore, and of Rome in particular, which was the object of special study to Vitruvius.

Vitruvius has also elaborately treated the subject of dialing in as many as four chapters (Bk. IX. chapters I, II, VIII, IX).

In this matter of dialing, as in many others, Vitruvius of course differs in certain details from the Mānasāra. For instance, regarding the principles of dialing each of the twelve months is, in the Mānasāra (VII), divided into three parts of ten days each and the increase and decrease of shadow are calculated in these several parts of the different months. Vitruvius (Book IX, chapter VIII), on the other hand, discusses "the principles of dialing and the increase, and decrease of the days, not the shadow thereof in the different months.

In both these works, therefore, this introductory section comprises exactly eight chapters which bear similar titles and deal with the same subjects practically in the same way.

Town planning is the next topic treated in both the works and it covers exactly two chapters both in Vitruvius (Book I, chapters VI, VII), as well as in the Mānasāra (chapters IX, X).

The Mānasāra describes the subject under two heads, *Grāma-lakshaṇa* and *Nagara-vidhāna*, and three categories, village, town, and fort. Villages are divided into eight classes, called *daṇḍaka*, *sarvatobhadra*, *nandyāvarta*, *padmaka*, *svastika*, *prastara*, *kārmuka*, and *chaturmukha*; each of these as the names indicate, represents a particular design and layout. Towns are also divided into eight classes: *rājdhāni*, *nagara*, *pura*, *nagarī kheṭa*, *kharvaṭa*, *kubjaka*, and *pattana*. These refer more to the situation and distribution of buildings than to their shapes or designs.

Forts are first divided into eight classes: *sibira*, *vāhinimuka*, *sthānīya*, *droṇaka*, *samvidha* or *vardhaka*, *kolaka*, *nigama*, and *skandāvāra*. According to their situations, they are further classified into mountain fort (*vanadurga*), water fort (*jalu-durga*), chariot fort *ratha-durga*), gods' fort (*deva-durga*), clay fort (*paṅka-durga*) and mixed fort (*misra-durga*). The mountain fort is subdivided into three classes, as it may be built on the top of the mountain, in the valley, or on the mountain slope.

According to the Mānasāra there is, however, not much difference between a village, a town, and a fort. The town is the extension of a village. And the fort is in many cases nothing more than a fortified town. There seems to be only this difference that a fort is chiefly meant for purposes of defence, while a village or town is mainly intended for habitation and commerce. But the village scheme seems, all the same, to have originated from the plan of the military camp.

Each village is surrounded by a wall made of brick or stone. It is supported by ramparts. Boyond

this wall there is a ditch broad and deep enough to cause serious obstruction in the event of an attack on the village. There are generally four main gates at the middle of the four sides, and as many at the four corners. Inside the wall there is a large street running all round the village. Besides, there are two other large streets, each of which connects two opposite main gates. They intersect at the centre of the village where a public temple or hall is generally built for the meeting of the villagers. The village is thus divided into four main blocks, each of which is again sub-divided into many blocks by streets, which are always straight, and which run from one end to the other of a main block. The two main streets crossing at the centre have houses only on one side facing the street. The ground floor of these houses on the main streets consists of shops. Surrounding street also has houses only on one side. These houses are mainly public buildings, such as schools, colleges, libraries, guest-houses, liquor saloons. All other streets generally have residential buildings on both sides. The houses high or low are always uniform in make. The drains and sewers are made towards the sloping of the village. Tanks and ponds are dug in all the inhabited parts and located in such quarters as can conveniently be reached by a large number of inhabitants. The temples of public worship as well as the public commons, gardens, and parks are similarly located. The people of the same caste or profession are generally housed in the same quarter. The habitation of the dead body burners (*chāndālas*) as well as the places for cremation are located outside the village wall to the north-west in particular. The temples of fearful deities such as Chāmundā are also located outside the wall.

A town may be situated from east to west or from north to south according to the position it occupies.

There should be one to twelve large streets in a town. It should be built near a river or a mountain and should have facilities for trade and commerce with foreigners. Like a village it should be furnished with walls, moats, ditches, gates, drains, parks, commons, shops, exchanges, temples, guest-houses, colleges, etc. Towns were largely inhabited by the king, his court, and the traders.

Forts are also surrounded with strong walls and large and deep ditches. The wall is made of brick, stone, and similar lasting materials. It is at least eighteen feet in height and its thickness at the base is at least nine feet. The wall is provided with watch towers.

The fortified cities are specially honoured with the palaces of the king, the princes, priests, ministers, and military officers. There are also humbler dwellings as well as courts of justice, arsenals, traders' booths, shops, work artisans, various assembly halls, dancing halls, liquor saloons, and gambling halls.

According to Vitruvius (Book I, chapter V)—

"When we are satisfied with the spot fixed on for the site of the city, as well as in respect of the goodness of the air, as of the abundant supply of provisions for the support of the population, the communications by good roads, and river or sea navigation for the transport of merchandise* we should take into consideration the method of constructing the walls and the towers of the city. From the exterior face of the wall towers must be projected, from which an approaching enemy may be annoyed by weapons, from the ambrasures of those towers, right and left, an easy approach to the wall must be provided against; indeed they should be surrounded by

*Compare (Chanakya's saying)—धनिकः श्रोत्रियो राजा नदी वैद्यश्च पञ्चमः । पञ्च यत्र न विद्यन्ते तत्र वासं न कारयेत् ॥

uneven ground, and the roads leading to the gates should be winding and turned to the left from the gates. By this arrangement the right sides of the attacking troops, which are not covered by their shields, will be open to the weapons of the besieged."

"The thickness of the walls should be sufficient for two armed men to pass each other with ease. The walls ought to be tied, from front to rear, with many pieces of charred olive wood; by which means the two faces, thus connected, will endure for ages . . . ."

"The distance between each tower should exceed an arrow's flight . . . . "The walls will be intercepted by the lower parts of the towers where they occur, leaving an interval equal to the width of the tower, which space the tower will consequently occupy. The towers should be made either round or polygonal. A square tower is a bad form, on account of its being easily fractured at the quoins by the battering ram; whereas the circular tower has this advantage, that when battered, the pieces of masonry, whereof it is composed, being cuneiform, cannot be driven in towards their centre without displacing the whole mass. Nothing tends more to the security of walls and towers, than backing them with walls or terraces; it counteracts the effects of rams as well as of undermining . . ."

"In the construction of ramparts, very wide and deep trenches are to be first excavated; the bottom of which must be still further dug out for receiving the foundation of the wall. This must be of sufficient thickness to resist the pressure of the earth against it. Then, according to the space requisite for draining up the cohorts in military order on the ramparts, another wall is to be built within the former, towards the city. The outer and inner walls are then to be connected by cross walls, disposed on the plan after the manner of the teeth of a comb or

a saw, so as to divide the pressure of the filling in earth into many and less forces, and thus prevent the walls from being thrust out. (The materials are stated to be) what are found on the spot, such as square stones, flint, rubble stones, burnt or unburnt bricks." (Book I, chapter V.)

"The plan of the city should not be square, nor formed with acute angles, but polygonal; so that the motions of the enemy may be open to observation." (Book I, chapter V.)

"The lanes and streets (of which no details are given) of the city should be set out, the choice of sites for the convenience and use of the state remains to be decided on; for sacred edifices, for the forum, and for other public buildings. If the place adjoins the sea, the forum should be seated close to the harbour; if inland, it should be in the centre of the town. The temple of the gods, protectors of the city, as those of Jupiter, Juno, and Minerva, should be on some eminence which commands a view of the greater part of the city. The temple of Mercury should be either in the forum or, as also the temple of Isis and Serapis, in the great public square. Those of Apollo and Father Bacchus near the theatre. If there be neither amphi-theatre nor gymnasium, the temple of Hercules should be near the circus. The temple to Mars should be out of the city, in the neighbouring country, that of Venus near to the gate. According to the revelations of the Hetrurian Haruspices, the temples of Venus, Vulcan, and Mars should be so placed that those of the first be not in the way of contaminating the matrons and youth with the influence of lust; that those of Vulcan be away from the city, which would consequently be freed from the danger of fire; the divinity presiding over that element being drawn away by the rites and sacrifices

performing in his temple. The temple of Mars should be also out of the city, that no armed frays may disturb the peace of the citizens, and that this divinity may, moreover, be ready to preserve them from their enemies and the perils of war. The temple of Ceres should be in a solitary spot out of the city, to which the public are not necessarily led but for the purpose of sacrificing to her. This spot is to be reverenced with religious awe and solemnity of demeanour, by those whose affairs lead them to visit it." (Book I, chapter VII.)

It should be observed that in the Mānasāra eight distinctive plans of villages, and some twenty-five varieties of commercial cities and military forts have been described with all details. In town planning the Indian authority has recommended, almost all the suitable designs, square, rectangular, polyogonal. But vitruvius recommends only the polygonal one. In the matter of the disposition of temples within the city wall and outside, the two authorities very strikingly correspond. In both the treatises the fearful deities are similarly located outside the city wall.

The following seven chapters* (XI—XVII) in the Mānasāra serve the purpose of a preamble to the subsequent chapters dealing with buildings.

The first of these (XI) is named, "*Bhūmilamba*" literally height of storey, in the Mānasāra. It is defined in the Kāmikāgama as the dimensions of the four sides. The contents of the chapter in the Mānasāra describe in detail the measurement of length, breadth, and height of buildings of one to twelve storeys assigned to persons

*Of these seven introductory chapters the twelfth on foundation (garbha-nyāsa) should have been in place of the eleventh [which treats of dimensions of buildings (*bhūmi-lamba*) as in Vitruvius.]

of different ranks. The five forms, namely, square, rectangular, round, octagonal, and oval, are prescribed for buildings of different classes, *jāti*, *chhanda*, *vikalka*, and *ābhāsa*. These shapes are equally applicable to religious, military, and residential buildings. A palace of five to twelve storeys is stated to suit the emperor or the universal monarch, highest in rank among the nine classes of kings. Residences of one to three storeys are assigned to heir apparent and the chief feudatories, and so on.

The title of the corresponding chapter of Vitruvius (Book VI, chapter VIII) is more significant. It is called "Forms of houses suited to different ranks of persons." As in the Mānasāra buildings are divided exactly into five classes, though the criteria of classification are different. It is stated (Book III, chapter II) that "There are five species of temples, whose names are, Pycnostylos, that is, thick set with columns: Systylos, in which the columns are not so close: Diastylos, where they are still wider apart: Araeostylos, when placed more distant from each other......, Eustylos, when the inter-columnation ......is of the best proportion." "The conditions of temples are distinguished," it is further stated, (Book III, chapter I) by their different forms. First, that known by the appellation In Antis, then the Prostylos, Peripteros, Pseudodipteros, Dipteros, and Hypaethros." "Circular temples are constructed, of which some are Monopteral......others are called Peripteral" (Book IV, chapter VIII).

As regards the distribution of buildings it is stated that (Book IV chapter III) "temples of the Doric order are erected to Minerva, Mars, and Hercules; on account of whose valour, their temple should be of masculine proportions, and without delicate ornament. The character of the Corinthian order seems more appropriate to Venus, Flora, Proserpine, and Nymphs of Fountains; because

its slenderness, elegance, and richness, and its ornamental leaves surmounted by volutes, seem to bear an analogy to their dispositions. A medium between these two is chosen for temples to Juno, Diana, Bacchus, and other similar deities, which should be of the Ionic order, tempered between the severity of the Doric and the slenderness and delicacy of the Corinthian order." (Book I, chapter II.) As regards the secular buildings, it is laid down that "The houses of bankers and receivers of the revenue may be more commodious and elegant than those of persons of middling condition in life. For advocates and men of literature, houses ought to be still handsomer and more spacious, to suit the reception of persons on consultations. But for nobles, who in bearing honours, and discharging the duties of the magistracy, must have much intercourse with the citizens, princely vestibules must be provided, lofty atria, and spacious peristylia, groves, and extensive walks, finished in a magnificent style......If, therefore, houses are erected, thus adapted to the different classes of society......there will be nothing to reprehend, for they will be suitable to their destination......I have thus described," concludes Vitruvius, " the proportions of town residences as I promised. I shall now proceed to those of houses in the country." (Book VI, chapter VIII).

It is needles to point out that the subject matter of this chapter is virtually the same in both the authorities. The small differences are due to the local conditions and requirements of the two different countries.

The next chapter (XII), called *Garbha-nyāsa* in the Mānasāra, deals with the foundations whereupon buildings, villages or tanks are built. The foundation is excavated in the best ground selected for a structure to the depth of a man's height with uplifted arms. It is laid down that the bottom of the pit thus excavated must be

rocky or watery, in other words, it must reach rock or water. It implies that the best soil for receiving foundation, when it is not erected on water, is rock, gravel, or closely pressed sandy earth.

The depth of the foundation-cave is equal to the height of the basement. The four corners and sides, built of brick or stone, are equal. This cave is filled with water and ten kinds of earth, such as earth from an ant-hill, a crab-cave, etc., is placed at the bottom, and closely pressed and hardened by means of wooden hammers shaped like the elephant's foot. Portions of certain plants are then deposited on the four sides; the root of the blue-lotus to the east, the root of white-lotus to the south, and so on. Upon these are placed grains of ten kinds of cereals such as phaseolus mungo, phaneolus radiatus, dolichos uniflorus, sesamum idicum, and so on. The vault is built thereon, the details of which need hardly be repeated here. Upon such strong foundations, the strength whereof varies according to the weights of the buildings above, various structures are constructed. "When we are satisfied," says Vitruvius (Book I, chapter V.), "with the spot fixed on for the site of the city......their foundations should be carried down to a solid bottom, if such can be found, and should be built thereon of such thickness as may be necessary for the proper support of that part of the wall which stands above the natural tend of the ground. They should be of the soundest workmanship and materials, and of greater thickness than the walls above." The importance of solid ground is emphasised and it is again stated (Book III, chapter III): "If solid ground can be come to, the foundations should go down to it and into it, according to the magnitude of the work, and the substruction be built up as solid as possible. Above the ground of the foundation, the wall should be one-half thicker than the column it is to receive, so that

the lower parts which carry the greatest weight, may be stronger than the upper part......Nor must the mouldings of the bases of the columns project beyond the solid. Thus, also, should be regulated the thickness of all walls above ground. The intervals between the foundations brought up under the columns, should be either rammed down hard, or arched, so as to prevent the foundation piers from swerving. If solid ground cannot be come to, and the ground be loose or marshy the place must be excavated, cleared, and either alder, olive, or oak piles, previously charred, must be driven with a machine, as close to each other as possible, and the intervals, between the piles, filled with charcoal. The heaviest foundations may be laid on such a base.

These details so strikingly similar in both the authorities, can hardly be attributed to mere chance.

The next four chapters (XIII—XVI) in the Mānasāra deal with the column and its different parts, pedestal, base, shaft and entablature, and their various mouldings. Vitruvius also treats the subject in exactly four chapters (Book III, chapter III, Book IV, chapters I—III). But the titles of the chapters are a little different; they are named in the Mānasāra, *upapīṭha* or pedestal (XIII), *adhishṭhāna* or base (XIV), *stambha* or shaft (XV), and *prastara* or entablature (XVI); and Vitruvius calls them, 'columns and their ornaments' (Book III, chapter III), 'origin of the three sorts of columns and the Corinthian capital' (Book IV, chapter I), 'ornaments of columns' (Ibid, chapter II), and 'Doric proportions' (Ibid, chapter III).

"Vitruvius, in the Doric, Corinthian, and Tuscan orders, makes no mention of pedestals, and in the Ionic order he seems to consider them rather as a necessary part in the construction of a temple than as belonging to the order itself" (cf. Book V. chapter VII). In the Mānasāra

twelve kinds of pedestals are described with detailed measurements of the various mouldings of each pedestal. A comparison of these with similar details of pedestals, quoted in full in the writer's Dictionary from European authorities other than Vitruvius, makes it clear that the Indian pedestals surpass the Greco-Roman pedestals in variety, beauty of proportion and the richness of ornament.

As regards the base also there is in the Mānasāra a large variety of types, being sixty-four in number, described in detail with their mouldings and ornaments. A comparison of the details gathered together in the writer's Dictionary will show that the Indian bases and pedestals also are made more systematically and afford a greater variety of proportions than those of the Greco-Roman orders. In European orders the forms and dimensions of both base and pedestal are fixed by invariable rules with respect to the orders in which they are employed, while in the Indian orders the choice is left to the option of the artists.

There are, however, more similarities between the Indian and the Greco-Roman entablature, consisting of four parts, capital, architrave, frieze and cornice. But the massiveness of the Indian entablature offers a striking contrast to the lightness of the Grecian. This is shewn by a comparison of details, given in the writer's Dictionary, of eight kinds of Indian and some five kinds of Greco-Roman entablatures.

But the point to be clear about is whether or not there is some fundamental resemblance between the Indian and the Greco-Roman columns as a whole. This is a crucial point; because the column in a building is stated by authorities to be the regulator of the whole composition; and it is the one feature of the ancient architecture which 'illustrates its rise and progress as well as its perfection and weakness.'

Like the five Greco-Roman orders, called Doric, Ionic, Corinthian, Tuscan and Composite, columns in ancient India were also divided into five classes or orders.

In the Mānasāra they are called *Brahma-kānta Vishṇu-kānta*, *Rudra-kānta*, *Śhiva-kānta*, and *Skanda-kānta*. These divisions are based on the general shapes. With respect to dimensions and ornaments they are called *Chitra-karṇa*, *Padma-kānta*, *Chitra-stambha*, *Pālika-stambha*, and *Kumbha-stambha*.

In the Matsya-purāṇa, the Bṛihat Samhītā, and the Kiraṇa-tantra they are called *Ruchaka*, *Vajra*, *Dvi-vajra*, *Pralīnaka* and *Vritta*. In the Supra-bhedāgama the names of the five orders are *Śri-kara*, *Chandra-kānta*, *Saumukhya Priyā-darsana* and *Śubhankarī*. This last one is expressly stated to be the Indian composite order, being a compound (*misrita*) of *Saumukhya* and *Priya-darsana*, exactly like Greco-Raman Composite order, which is a compound of Corinthian and Ionic.

Between the European and the Indian columns, there is a point of difference. Of the Greco-Roman orders, the names of the five orders have been left unchanged, while in India the names of the five orders have varied in various treatises referred to above. It is true all the same that the criteria of divisions are essentially the same in all these authorities. This variation of the names of five orders can perhaps be explained away. The names of the Greco-Roman orders according to Vitruvius and other European authorities referred to in the Encyclopedia of Architecture by Gwilt are geographical.

Doric is derived from the species of columns first found in the cities of Doria. That species of which the Ionians or the inhabitants of Ion were the inventors has received the appellation of Ionic. Callimachus constructed columns after the model of the tomb in the country about Corinth; hence this species is called Corinthian. The

Tuscan order has reference to the country of Tuscany in Italy. The Composite is compound of Ionic and Corinthian.

In India, on the other hand, the names of the orders were based on the shapes of the columns. And as the Indians are comparatively more spiritualistic and sentimental rather than critical in temperament and imagination, they chose mythological and poetical names according to the spirit of the times when these various works were composed. Thus in the Mānasāra we see the orders bearing the names of mythological deities, Brahmā, Vishṇu, Rudra, Śiva and Skanda; as well as the poetical names like *Chitra-karṇa* (variegated ear), *Chitra-stambha* (variegated shaft), *Padma-kānta* (graceful like lotus), *Kumbka-stambha* (jug-shaped shaft), and *Pālika-stambha* (shaped like a measuring pot). In the Āgama, the names are more poetical—*Śrīkara* (beautifying); *Chandra-kānta* (graceful like the moon), *Saumukhya* (of a charming face), and *Śubhaṅkar* (auspicious). In the Purāṇa, the Bṛihat-samhitā, and the Kiraṇa-tantra, the names combine beauty and utility—*Ruchaka* (pleasing), *Vritta* (round and dignified), *Vajra* (beautiful and solid like the club). *Dvi-vajra* (doubly so), and *Pralīnaka*.

With regard to the names and functions of the component parts of the column the variation is a little less marked. The number of these subservient parts, called mouldings and common to all orders, is very significant. Thus in the Mānasāra, which, of almost all the treatises, deals separately and exhaustively with the pedestal, the base, the column or shaft, and the entablature, mention is made in connection with the pillar of five mouldings apparently of the shaft. They are called *bodhikā*, *mushṭi-bandha*, *phalaka*, *tāṭikā*, and *ghaṭa*. But the total number of mouldings, when base, pedestal, and entablature are also taken into consideration is forty-seven.

The Supra-bhedāgāna describes two sets of seven mouldings; one set referring to the column of the main building and the other to that of the pavilion. They are called respectively *daṇḍa*, *maṇḍi*, *kaṇṭha*, *kumbha*, *phalakā*, *vīra-kaṇṭha*, and *potikā*, and *bodhikā*, *uttara*, *vājana*, *mūrdhikā*, *tulā*, *jayanti*, and *tāla*. This increasing number of mouldings has reached the significant number of eight in the Matsya-purāṇa, the Bṛihat-samhitā, and the Kiraṇa-tantra, and bears the very same eight names—*vahana*, *ghaṭa*, *padma*, *uttaroshṭha*, *bābulya*, *hāra*, *tulā*, and *upa-tulā*.

The component mouldings of the Greco-Roman orders are also exactly eight in number; and like the five orders themselves their names have remained invariable ever since their introduction, though most of them have been given more than one name. They are called (1) the ovolo, echinus, or quarter round; (2) the talon, ogèe, or reversed cyma; (3) the cyma, cyma-recta, or cymatiam; (4) the torus; (5) the scotia or trochilos; (6) the cavetto, mouth, or hollow; (7) the astragal, and (8) the fillet, listel, or annulet.

Some of the eight mouldings of the Indian order can be identified, with a reasonable certainty, with the corresponding mouldings of the Greco-Roman order.

Padma for instance implies lotus (petal), and cyma also suggests the same thing. *Uttaroshṭha*, literally the lower lip, and the caveto, mouth, or hollow are apparently the same. *Hāra*, meaning chain, seems to imply the same object as the torus, bead or astragal. *Ghaṭa* means a pot; it may correspond to the ogèe, talon or reversed cyma. *Vahana* is that which supports anything, and the abacus also serves the same purpose; so they may correspond to each other. *Tulā* and *upa-tulā* otherwise called *vājana* and *uttara* seem to correspond to the fillet, listel or annulet.

The proportionate measurement of the columns is another important point of comparison. The details are discussed in the writer's Dictionary. The first Indian sort

is six diameters high, the second seven diameters, the third eight diameters, the fourth nine diameters and the fifth ten diameters high.

"Concerning the proportions of columns", says Rām Rāz (page 38), "the second sort of column in the Hindu architecture may be compared with the Tuscan, the third with the Doric, the fourth with the Ionic, and the fifth with the Corinthian or Composite pillar." He further adds, "there are other columns in the Indian architecture, not only one diameter lower than the Tuscan, but one to two diameters higher than the composite." Same is also the case with the European columns. "The orders and their several characters and qualities," says Gwilt (2538), "do not merely appear in the fixed species of columns into which they have been sub-divided, but are distributed throughout the edifices to which they are applied."

"Both the Indian and Grecian columns are diminished gradually in their diameter from the base to the summit of the shaft, a practice which has never been observed in the Egyptian; on the contrary, a diametrically opposite rule has been observed in their shafts, which are made narrower at the bottom than at the top. . . . The proportion in which the diminution at the top of the columns of the two former (Indian and Greco-Roman) is made seems to have been regulated by the same principle, though not by the same rule. The general rule adopted by the Hindu architects in this respect is, that the thickness at the bottom, being divided into as many parts as there are diameters in the whole height of the column, one of these parts is invariably diminished at the top; but in the Grecian and Roman architecture, the diameter of the upper part of the shaft, in a column of fifteen feet in height, is made one-sixth less than its thickness at the base; and in a column of fifty feet, the diminution is one-eighth. The higher the columns are, the less they

diminish, because the apparent diminution of the diameter in columns of the same proportion, is always greater according to their height, and this principle is supposed to have been discovered with greater scientific skill, and is adduced as one of the proofs of the highly refined taste of the Greeks: but we observe that precepts derived from the same principle have been taught and practised in India from time immemorial."

The point at issue is not the actual identification. The striking similarities in the names of the mouldings, like *padma* or cyma, *hāra* or bead, or in the names of orders like the *Misrita* or Composite may sometimes be attributed to inexplicable accidents. But in view of other striking similarities between Vitruvius and the Mānasāra, the classification of orders into exactly five; and the division of subservient parts, called mouldings and common to all the orders, into eight and also the proportionate measurement varying equally from six to ten diameters, and tapering almost in the same way seems to have been due to some thing more substantial than mere chance. An influence, direct or indirect, of the one upon the other seems beyond doubt. I venture to think, further, that there might have been a relation of indebtedness between the two authorities.

The concluding chapter of this section in the Mānasāra deals with joinery. No separate treatment has been accorded by Vitruvius to this subject.

The next chapter (XVIII) in the Mānasāra is a summary of details concerning buildings of various storeys and kinds described in chapters XIX—XXX. The chapters following XXXI—XXXVI, deal with attached buildings of various descriptions and requirements. The chapter XXXVII refers to the first entry into newly built house. Doors are separately described in two chapters XXXVIII—XXXIX; so also the royal palaces and courts are described

in chapters XL—XLII. Cars and chariots, couches, and thrones are treated in the next three chapters XLIII—XLVI. Arches are separately described in chapter XLVII, so also the theatre (*Madhya-raṅga*) is treated in chapter XLVIII. And this architectural portion of the Mānasāra ends with the descriptions of crowns (chapter XLIX) and of ornaments and articles of furniture (chapter L).

The sculptural portion of the work (chapters LI—LXX) deals with the art of carving and measuring images. This portion practically comprises illustrations of the *tāla* measures. Vitruvius, as we shall show presently, has not treated the subject separately; he has mixed it up with the architectural description. With regard to these subjects the comparison between the Mānasāra and Vitruvius need not be lengthy. Both these authorities in matters of detail must necessarily differ from each other even if the one were translaled from the other: because the local conditions and national requirements were entirely different regarding not only the residential buildings but also temples. On the broad lines of methods and principles, however, the comparison can be briefly continued with the expectation of fruitful results.

Thus, in the Mānasāra, the whole compound of the house is divided into five courts (chapter XXXI), each of which is furnished with a gate-house (chapter XXXIII) and a large number of detached buildings is also built within each court (chapters XXXII, XXXVI, XIX—XXX).

Vitruvius also divides the whole compound into exactly five courts (Book VI, chapters III—VII). "There are," says Vitruvius, "five species of courts; which receive their names from their forms. The Tuscan, the Corinthian, the Tetrastylon (with four columns), the Displuviatum (open at the top), and the Testudinatum (roofed)."

In the Mānasāra also, it should be noted, five technical names have been given to these five courts, *antarmaṇḍala* (innermost court), *anta-nihārā* (the second court), *madhya-nihārā* (the middle court), *prākāra* (the fourth court) after which the chapter has been named, and which is stated to be first introduced in the Mānasāra, though as many as seven courts are described in the Mṛichchhakaṭika. The fifth one is called *mahā-maryādā* or 'extreme boundary.' Thus in the Mānasāra the courts receive their names from their situations, and not from their forms. Forms are discussed in the Mānasāra also. In fact the treatment of this subject like all others is by far the more exhaustive in the Mānasāra. Even the five gatehouses of the five courts have been treated at great length in a separate chapter (XXXIII) and given five technical names, *dvāra-sobhā*, beauty of the gate, belonging to the *antarmaṇḍala* or first court; *dvāra-sālā* (lit. 'gate-house of the second court), *dvāra-prāsāda* (lit. edifice of the gate), *dvāra-harmya* (lit. palace of the gate) and *mahā-gopura* (lit. great gate-house).

Within these courts buildings of different requirements have been similarly distributed by the two authorities. For instance in the Mānasāra chapter XXXVI is called *Gṛiha-mānā-sthana vinyāsa* literally meaning 'location and measurement of house, and chapter XXXII is called *Parivāra-vidhāna,* meaning the buildings for the members of the family (of gods). The corresponding chapters (Book VII, chapters I, II, IX) are named by Vitruvius 'situation of buildings according to the nature of different places,' 'proportions of private buildings to suit the nature of the sites,' and 'proportions of houses in the country.' Detached buildings situated both within the compound and outside have been described in the Mānasāra in two very large chapters (XXXIV, XXXV) called *Maṇḍapa* and *Śālā*. The term *Maṇḍapa* is used to imply first a

house or pavilion built in a village or on the bank of a sea, river, tank or lake; secondly, all the detached buildings within a compound which is divided into five courts, lastly it implies various sorts of rooms in a temple or residential building. *Śālā* also implies almost the same sort of buildings; but they are more commodious and their forms and twelve storeys are taken into special consideration. The chapter VI. (Book I) called by Vitruvius 'distribution and situation of buildings within the walls' may be compared with '*Maṇḍapa*' and '*Śālā*' with respect to general principles and methods. But Vitruvius's treatment of the subject is comparatively brief. The similar extremely brief treatment of Vitruvius with regard to an individual building also becomes obvious when his "Arrangement and parts of Grecian houses" and "Interior of the cell and the arrangement of Pranaos" described in two small chapters (Book VI, chapter X, book IV, chapter IV) are compared with the exhaustive description of the similar subjects detailed in some thirteen chapters (XVIII—XXX) in the Mānasāra.

Doors are separately described by both the authorities. Vitruvius calls the chapter "Proportions of the doors of temples" (Book IV, chapter VI). In the Mānasāra the subject is treated in two chapters (XXXVIII, XXXIX), called '*Dvāra-sthāna*' (location of doors) and '*Dvāra-māna*' (measurement or proportions of doors). Both authorities classified doors under three species. Vitruvius calls them Doric, Ionic, and Attic; and in the Mānasāra they are called *Chhanda*, *Vikalpa*, and *Ābhāsa*. Here is a striking point of similarity with respect to an important omission. In the Mānasāra the *jāti* class always goes with the other three classes mentioned here. Vitruvius has also omitted Corinthian and Tuscan which generally go with Doric and Ionic. In the Mānasāra the height of the door is stated to be, as a general rule, twice its breadth. "Their width,"

says Vitruvius, "is found by dividing the height into two parts and a half, and taking one and a half for the width below." Single folded as well as double folded doors are mentioned in the Mānasāra. Vitruvius has referred also to four-fold doors. The Indian doors are properly decorated with foliated and floral ornaments as well as the images of deities. "These doors," says Vitruvius, "are not to be inlaid (cerestrota), nor in two folds, but single folded, and to open outwards". According to Vitruvius doors are generally constructed in the middle of the front wall. But according to the Mānasāra doors may also be constructed sometimes not in the centre of the frontage, but on either side of the middle.

Windows are not separately described by Vitruvius. But in the Mānasāra a long description of them has been given at the end of the chapter XXXIII; similarly an account of stair-cases, omitted by Vitruvius, is found in the Mānasāra at the end of the chapter XXX. No separate mention has also been made by Vitruvius of arches to which subject an entire chapter (XLVI) has been devoted in the Mānasāra. Virtuvius has also left out the descriptions given in the Mānasāra of cars and chariots (chapter XLIII), couches (XLIV), thrones (XLV), crowns (XLIX), ornaments of the body and articles of house furniture (L), as well as the ornamental tree (XLVIII).

In the Mānasāra, on the other hand, a very brief reference is made to a subject resembling a theatre, to which Vitruvius has devoted several chapters (Book V, chapters III—IX). Vitruvius has not treated separately the royal palaces found in the Mānasāra (chapters XL—XLII), which has, however, had no place in it for description of special buildings, such as Forum and 'Basilica, treasury, prison, and curios,' 'harbours and other buildings in water' (Book V, chapters I, II, XII). Building materials, though frequently mentioned, are not described in the Mānasāra in separate

chapters. Vitruvius has devoted some eight chapters to it (Book II, chapters III—X), bricks (compare Mānasāra, chapter XII last part), sand (M. XII), lime (M. LI), Pozzolona, stone quarries (M. XV), timber (M. XV) and firs, called Supernas and Infernas, and of the Apennines.

Vitruvius deals with painting and preparations of colours in the most part of a book (VII) of fourteen chapters. This subject as well as Vitruvius's books (VIII—X) on Instruments, Machines and Engines have had no place in the Mānasāra. In place of these matters some twenty chapters (LI—LXX) of the Mānasāra have been devoted to sculptural matters to which only the following brief and casual reference has been made by Vitruvius (Book III, chapter I).

"In truth they (symmetry and proportion) are as necessary to the beauty of a building as to that of a well-formed human figure, which nature has so fashioned, that in the face, from the chin to the top of the forehead, or to the roots of the hair, is a tenth part of the height of the whole body. From the chin to the crown of the head is an eighth part of the whole height, and from the nape of the neck to the crown of the head the same. From the upper part of the breast to the roots of the hair a sixth; to the crown of the head a fourth. A third part of the height of the face is equal to that from the chin to the under side of the nostrils, and thence to the middle of the eyebrows the same; from the last to the roots of the hair, where the forehead ends, the remaining third part. The length of the foot is a sixth part of the height of the body. The fore-arm a fourth part. The width of the breast a fourth part. Similarly have the other members their due proportions by attention to which the ancient painters and sculptors obtained so much reputation. . . . . ."

"The naval is naturally placed in the centre of the human body, and, if in a man lying with his face upward, and his hands and feet extended, from his naval as the centre, a circle be described, it will touch his fingers and toes. It is not alone by a circle, that the human body is thus circumscribed, as may be seen by placing it within a square. For measuring from the feet to the crown of the head, and then across the arms fully extended, we find the latter measure equal to the former; so that the lines at right angles to each other, enclosing the figure, will form a square."

"If nature, therefore, has made the human body so that the different members of it are measures of the whole, so the ancients have, with great propriety, determined that in all perfect works, each part should be some aliquot part of the whole; and since they direct, that this be observed in all works, it must be most strictly attended to in temples of the gods, wherein the faults as well as the beauties remain to the end of the time." This is all about the defects to which in the Mānasāra a whole chapter (LXIX) practically, one of the two concluding chapters of the work, is devoted. It is called '*Aṅga-dūshaṇa*' literally 'defects of the limbs.' In both the authorities the subject is discussed in connection with sculptural objects, but curious enough, defects and consequent penalties concerning images and idols have been entirely left out both by Vitruvius and the Mānasāra. Both the authorities have referred to the subject concerning buildings only. This sort of similarities cannot be due to mere chance.

"It is worthy of remark," says Vitruvius, "that the measures necessarily used in all buildings and other works, are derived from the members of the human body, as the digit, the palm, the foot, the cubit, and that these form a perfect number, called by the Greeks, "Téleios." Phonetically this is same as the *tāla* measure. In the above quotation

Vitruvius has briefly referred to only the eighth variety with which the male human figure is measured by the Indian authorities also. Details of the *tāla* measures given in the writer's Dictionary need not be repeated here. It should also be noted that in both the authorities the face from the chin to the crown of the head is taken as the standard of all the *tāla* measures which number ten in the Mānasāra.

The last point of comparison between Vitruvius and the Mānasāra is in respect of the linguistic style. The importance of this point can hardly be exaggerated. We have already pointed out that Śilpa-Śāstras or architectural treatises in India were written in a very peculiar style. Sanskritists like Dr. G. Bühler and Sir R. G. Bhandakar have truly branded it as the 'most barbarous Sanskrit.' The remark really means that all possible sorts of violation of the rules of grammar and rhetoric have been committed in the language of the Śilpa-Sāstra. The matter has been discussed elsewhere in great detail which need not be repeated here. One of the theses presented by the writer before the Leiden University and passed in his favour by that learned assembly after long discussion was this:

"The ungrammatical style of Sanskrit revealed in the branch of literature of which the Mānasāra is a representative, is due to the want of literary proficiency on the part of the professional architects, who seem to have been the authors of it." With this the following apology, for ungrammatical style, of Vitruvius (Book I, chapter I) may very fruitfully be compared.

"I beseech you, O'Caesar," says Vitruvius, "and those who read this my work, to pardon and overlook grammatical errors; for I write neither as an accomplished philosopher, an eloquent rhetorician, nor an expert grammarian, but as an architect: in respect, however, of my art and its

principles, I will lay down rules which may serve as an authority to those who build, as well as to those who are already somewhat acquainted with the science."

I cannot help thinking that if the writers of the Silpa-Śāstra, generally, and the author of the Mānasāra in particular, were conscious of the nature of their style they would certainly have added to their treatises an apology like that of Vitruvius. I, further, hold that this ungrammatical style is a very extraordinary and striking similarity between the Mānasāra and Vitruvius, inasmuch as such similarities are possible only in case of a literal translation or copying from one language to another by an unskilled hand.

There is yet another curious similarity between Vitruvius and the Mānasāra. It is regarding the title of both the works. Both are hidden in a mystery. Vitruvius's work bears practically no titles. It is called by his translators 'The architecture of Marcus Vitruvius Pollo.' It has been pointed out in the preface that the term 'Mānasāra' also admits of various interpretations. For sage, Mānasāra is a very unfamiliar name. No such sage is mentioned in the various branches of Sanskrit literature except in this newly discovered Vāstu-Śāstra. A king of Malwa, however, bore this name. As a derivative name, Mānasāra, meaning essence of measurement, and suitable for a work like this, might have some philological resemblance with 'mensuration'. The derivative meaning of the term 'Vitruvius' is uncertain. The point, however, to which attention is invited, is the curious similarity between the treatise of Vitruvius and the Mānasāra in respect of the uncertain significance of their titles.

There is also an uncertainty lurking over the ages in which the architecture of Vitruvius and the Mānasāra were composed. "It is likely that" the former "was

composed twenty-five years before the Christian era." This conjecture is based mainly on Vitruvius's mention of his patron Julius Caesar. But there is no mention of anybody under whose patronage the Mānasāra might have been composed.

The similarities so briefly outlined will be more convincing to those who have carefully studied both Vitruvius and the Mānasāra.

Those who are, however, inclined to think like myself and refuse to attribute all these affinities to mere chance will be anxious to find out the connecting link between the two authorities.

There is the expedition of Alexander the Great to explain the Grecian influence on the Gāndhāra sculpture. The 'questions of Menandar' may perhaps account for the title *Milandaphana*. There is again the *Romaka-sidhānta* to explain the influence of the Roman astronomy upon the Indian Jyotisha-Śāstra, which had, however, already established itself as one of the six essential limbs of the Veda, the most ancient existing lore of human learning. Similarly the art of building, which is intimately connected with all living beings, was developed by the ancient Hindus at the early Vedic period. But the Śilpa-Śāstra, which is but an analysis and commentary of the art, was necessarily evolved much later. There are reasons to think that the Mānasāra is not the first work, where the 'essence of measurement and the system of proportions' were codified in the form of Śāstra, though it may be the standard treatise.

Until, however, the missing link is found out, it is just possible to think that a third work or some floating traditions might have influenced both these treatises. It will, therefore, serve no useful purpose in trying to further develop the nature of the various similarities between Vitruvius and the Mānasāra. I would not, therefore, hazard an opinion at present regarding the influence, direct

or indirect, of the one upon the other. There are some arguments in favour of both to claim the priority. I shall be content, for the present, if the learned world be convinced that there are undeniable similarities between the two standard works and that these affinities are not accidental.

PERSIAN LOAN-WORDS

IN THE

RĀMĀYAN OF TULSĪDĀS.

BABURAM SAKSENA, M.A., Lecturer in Sanskrit.

1. The language of the Rāmāyan represents broadly the Awadhī of the 16th century A.D.[1] Awadhī, as it existed then, however, was ill-suited to the purpose of the author. It was a language of the common people and had been little used for literary purposes. Malik Muhammad Jāisī is the only known writer in Awadhī who preceded Tulsīdās. The author of the Rāmāyan adopted this language as the vehicle of his thought, since his aim was to make the story of Rāma, his God, popular amongst the masses of his country. In this he was eminently successful. But he had to flood his language with loan-words, to make up for the deficiency of vocabulary. His chief source for borrowing was the Sanskrit language together with the Prakrit languages. A large number of words have been taken from the court language of the time viz., Persian and a few from Arabic also through Persian. The present paper deals with these Persian and Arabic words.

2. These loan-words are all full words *i. e.*, words which express complete ideas *viz.*, substantives and adjectives. It is rare for a language to borrow particles, pronouns or verbs. When classified, these words fall under the following heads:—

(a) words to denote things newly introduced *e. g.*, *caugānā, pirojā, gaca, bājīgara, kāgaja;* *(b)* military

[1] Vide Baburam Saksena: Lakhīmpurī—a dialect of modern Awadhī § 16, J. A. S. B., XVIII (N. S.) No. 5.

words *e. g., phauja, kotala, tarakasa; (c)* words used in law-courts *e. g., sajāī, parawānā, bibākī, sahī, hawālē, bandīkhānā; (d)* words to address the noble classes *e. g., sāhiba, garībanewāja, siratāja, ganī; (e)* words denoting abuse or depreciation *e. g., kūra, khuārū, majūrī, poca, bihālu;* and *(f)* miscellaneous words generally used by the gentry *e. g., bidā, ādēsā, jamāta, awarēba, bāga.*

3. It is very natural that such words as express new ideas or denote things newly introduced should gain ground in the borrowing language. All efforts to substitute approximate translations from the language very generally fail. For instance in modern Awadhī such words as *lālṭēn, rēl, ṭikaṭ, samman, lillām* and *laṅkalāṭ* have come to stay. The military words as well as those of courts of law are also taken in a language, if the rulers—the conquering nation—stay in the conquered country for a pretty long time. The old military as well as administrative terms, owing to disuse, are forgotten by and by, while the current ones stay on. It is also generally that the words used to address the noble classes, the rulers become popular being very frequently in use since desired by the rulers themselves. The rulers, however, in turn shower abuses on the conquered people who take them up and use them against their own people.[1] As for the other words, "People will very often use foreign words where it would have been perfectly possible to express their ideas by means of native speech-material, the reason for going out of one's own language being in some cases the desire to be thought fashionable or refined

[1] It has been noticed that the servants brought down from the hills (Kumaon and Garhwal) to serve their masters in the plains of Northern India very easily pick up Hindustānī abuses and use them against their fellow-hillmen while speaking their own dialect. The same is the case with the Indian servants of European officers.

through interlarding one's speech with foreign words..."[1] This reason would operate to a great extent amongst a conquered people.

4. Once a foreign word is adopted in a language, it undergoes the changes necessary for assimilation into the language. Persian and Arabic loan-words also have undergone these changes. They may be classed as Phonetic and Grammatical.

PHONETIC CHANGES.

5. The following phonetic changes in these loan-words have taken place:—

(*a*) substitution of nearest Awadhī sounds for such Persian or Arabic sounds as are absent in Awadhī;

(*b*) such changes as make these loan-words fit in in the general phonological system of Awadhī;

(*c*) changes for the sake of metre;

(*d*) other phonetic changes.

6. Sustitution of nearest sounds is a common feature of a borrowing language. Modern Awadhī does not allow a consonant to be preceded by any nasal but of its own class. Arabic *imtihān*, therefore, becomes *intihān*, labial nasal being changed into dental to suit the dental consonant *t*. The same language does not admit a nasal after a consonant and, hence, when it borrows a word containing that conjunction it modifies it *e. g.*, English *signal* > Aw. *siṅgal*.

The sounds peculiar to Persian and Arabic undergo the following changes:—

(1) *q* ق > *k* e.g. *bākī* < *bāqī*, *lāyaka* < *lāyaq*;

(2) *kh* خ > *kh* e.g. *khabari* < *khabar*, *masakharī* < *mas-kharī*,

[1] O. Jesperson: Language, its Nature, Development and Origin, p. 210.

(3) *g* غ > *g* e.g. *garība* < *garīb*, *ganī* < *ganī*;
(4) *z* ز or ض > *j* e.g. *jīna* < *zīn*, *bāja* < *bāz*, *rajāī* < *razā* ;
(5) *z* ذ > *d* e.g. *gudarata* < *guzar*, *kāgada* < *kāgaz* ;
(6) *f* ف > *ph* e.g. *phauja* < *fauj*, *sarāpha* < *sarāfa* ;
N.B.—In one word, however, *f* > *p*, *pirojā* < *fīrozā* ;
(7) *sh* ش *or s* ص > *s e.g. nisānā* < *nishānā*, *sahanāī* < *shahnāī*, *sāhiba* < *sāhab*, *sahī* < *sahīh*;
(8) *h* ح > *h* e.g. *sahī* < *sahih*, *sāhiba* < *sāhab*;
(9) ' ع > *ā or is ineffective if coming with ā e.g. jamātā* < *jamā't.*

7. All bases in the Rāmāyan end in vowels.[1] Short vowels have, therefore, been added to such consonantal bases as were borrowed fron Persian and Arabic. Generally an *-a* or *-u* is added to such bases as are taken to be masculines (*vide* infra § 11), the *-u* ending being only a penultimate stage of the *-a* base[2], and we find *-a* and *-u* forms of the same base, foreign or otherwise, standing side by side in the Rāmāyan. For instance *pūc* > *poca* or *pocu*, *bāz* > *bāja* or *bāju*, *sāz* > *sāja* or *sāju*, *hāl* > *hālā* or *hālu*. Generally *-i* was added to such consonantal bases as were taken to be feminine e.g. *khabar* > *khabari*, *gardan* < *garadani*, *razā* > *rajāi*, *sazā* > *sajāi*.

In modern Awadhī all bases which earlier ended in *-a*, *-i* or *-u* have become consonantal, the last vowel coming in only when the pronunciation is specially slack and even then these vowels are pronounced very lightly.[3] It is probable that by the time of Tulsīdās these short vowels at the end of bases were lightly pronounced, though they were fully represented in writing and were counted for the purposes of metre as full vowels making syllables. The practice goes on

[1] *Vide* B. R. Saksena: Declension of the Noun in the Rāmāyan of Tulsīdās,§ (Ind. Antiquary LII 1923, p. 71.)

[2] *Vide* Declension of the Noun in the Rāmāyan§ 13 and § 18.

[3] *Vide* Lakhīmpurī Awadhī § 4.

in modern Awadhī also *e.g. cor* is written as *cora* but pronounced as *cor* and counted for metre as two syllables inspite of the pronunciation.

A long syllable if it is more than two syllables away from the end (and one of these two is long or has long effect) is shortened[1] *e.g. bāzār > bajāra, bībāqī > bibākī.*

Initial *v-* of a loan-word also, becomes *b-* in Awadhī *e.g. vidā, > bidā,* in common with the languages of East India *e.g. barana < varṇa, barisa < varṣa, bās < vaṁsa.*

Conjunction of dissimilar consonants was avoided from the time of the Prakrits either by an assimilation of consonants or by introducing *svarabhakti.* Similarly in the case of the present loan-words the *svarabhakti* comes in and avoids a conjunction *e.g.*

a as in *darabāra < darbār, bakasīsa < bakhshīsh*;
i as in *jinisa < jins*;
u as in *khuārū < khvār* through *khuvārū.*

The change of *i* into *e* was a common change in Prakrit or its *vice versa,* and the loan words have not escaped it sometimes *e. g. bebākī* or *bibākī, behālū* or *bihālū.*

8. Tulsīdās brings a few minor changes to bear upon his words, borrowed or otherwise, when he wants it for the purposes of regulating metre. The following changes have been noticed in the loan-words:—

(1) the quantity of a vowel, generally the last, changes *i.e.* a short vowel becomes long or *vice versa e.g.*

-a > -ā in *caugānā, nisānā, hālā*;
-ī > -i in *barābari*;
-u > -u-in *kabulī.*

(2) a nasal or an *anusvāra* becomes simple nasalization *e.g. kuṅgura > kā̃gūrā, andēsh > ā̃dēsā.*

[1] *Cf.* Lakhīmpurī Awadhī § 7.

9. The correct forms of certain loan-words have undergone a few phonetic changes which cannot be said to be necessary. These are:—
a > *i* in *sāhiba*, *a* > *e* in *newāje*, *u* > *a* in *kagūrā* and *majūrī*. It appears probable, however, that the incorrect forms of these words were generally spoken by foreigners and so these incorrect forms were taken in the Awadhī language. This is presumed since even now one hears *sāheb*, *newāzish*, *kaṅgūra* and *mazdūrī* from the lips of those who are expected to speak *sāhab*, *nawāzish*, *kuṅgura* and *muzdūrī* respectively for the above words.

The substitution of *c* for *j* in *kirica* < *kirija* is probably by contamination from *kurc*, a word in the same sense. The *t* for *d* in *supētī*, however, seems to be inexplicable unless it be an orthographical error.

Two words have shortened the number of their syllabic sounds *viz.* *majūrī* < *muzdūrī* and *kabārū* < *kārbār*. The contraction is hard to explain except on account of the frequency of use[1].

GRAMMATICAL CHANGES.

10. "When a word is borrowed it is not as a rule taken over with all the elaborate flexion which may belong to it in its original home; as a rule, one form only is adopted..."[2]. Awadhī generally borrows the crude form from the Persian. But once being borrowed, the loan-word is treated just like any other word of the language. The following are the changes which a Persian loan-word undergoes in the Rāmāyan:—

(1) A present participle is formed by adding an affix to a simple noun *e. g.* *gudarata* < *guzar* by adding -*ata*;

[1] *cf.* Lakhimpurī Awadhī §11.

[2] O. Jesperson : Language p. 213

(2) a past participle is formed from a simple noun *e. g. dāgē* < *dāg*, *newājē* < *nawāz*;

(3) an adjective from a noun *e. g. pharāka* < *farq*;

(4) an oblique case is given to a noun *e. g. badalē* < *badal*, *sādē* < *sāda*, *sāhibahī* < *sāhab*, *palakanha* < *palak*;

(5) an Indo-Aryan prefix is added to a loan-word *e. g. su-sāhiba* < *sāhab*, *kusāju* < *sāz*;

(6) an Indo-Aryan word is substituted for a Persian loan-word in a compound, the whole resulting in a hybrid compound *e. g. sira-taja* < *sar-tāja*; also *cf. bhaya-khaya-bājaḥ.*

GENDER OF LOAN-WORDS.

11. Awadhī has only two genders—masculine and feminine, the neuter nouns of Sanskrit, as pointed out by Beames[1], having generally been turned into masculines. Persian, however, has no gender from a grammatical point of view[2]. Persian words borrowed by Awadhī, therefore, had to adopt one of the two genders.

12. Two principles seem to operate *generally* in giving gender to loan-words. Firstly, if the borrowing language happens to possess a word approximating in sense to the loan-word, the gender of such a word is given to the loan-word also *e. g.* the word *rēl* (Eng. 'rail' used in the sense of train in India by common people) is of the feminine gender in Awadhī on the model of *gāṛī* (conveyance). Or, the word "letter" used by the educated Hindustānī people while speaking their own language is sometimes masculine and sometimes feminine. A man from Benares would generally say "*leṭar āī hai*" while a man from Moradabad would say "*leṭar āyā hai.*" This is because the usual Hindi word for expressing the sense of the word "letter" is

[1] *Vide* John Beames: Comparative Grammar of the Modern Aryan Languages of India, Vol. II, p. 147.

[2] *Vide* E. H. Palmer: Simplified Grammar of Hindustānī, Persian and Arabic, pp. 31-32.

ciṭhī (feminine) at Benares and *khat* (masculine) at Moradabad. It is on this principle that *gardani* (Skt. *grīvā*), *khabari* (Skt. *vārtā*), *kitāba* (Pkt. *pothī*) *tārikh* (Skt. *tithi*) are feminine while *soru* (Skt. *kolāhala*), *kāgaja* (Skt. *patra*) are masculine.

Secondly, if the language does not possess any word approximating in sense to the loan-word, it is given the gender which that type of native words takes in the language *generally*. For instance the word *lāin kiliar* (Eng. line clear) is treated as masculine in Awadhī since the consonantal bases are generally masculine. It is on this principle that *naphīrī*, *majūrī*, *sàhanāī*, *barābari* and *masakharī* are feminine while *gaca*, *caugānā*, *jahāja* and *hunara* are masculine.

N. B.—It should not, however, be supposed that the above principles operate very strictly. Examples which set them at nought are also many, but still they appear to be the *general* principles.

LIST OF THE WORDS.

13. Below is given a list of the loan-words from Persian and Arabic, found in the Rāmāyan.[1]

AWADHI.		LOAN-WORD.
Ādēsā, 287	...	Per. *andēsha* (from *andēshīdan* to reflect)—thought, doubt.
Awarēba, 21, 262, 280		Per. *ūrēb*—inverted, transposed, T. D. uses it as a noun—'deceit'.
Kāgūrā, 423	...	Per. *kuṅgura*—an ornamental cordon, balustrade.
Kabārū, 196	...	Per. *kārbār* or *kār-o-bār*—business.

[1]The references are to the pages of the *Rāmacharitamānasa* of the N. P. Sabh, Benares (*Tulsī Granthāvalī* Vol. I.). It may be also gratefully noted that Platts: Hindustānī Dictionary and Steingass: Persian-English Dictionary have been freely consulted for the etymology of these words.

Kabulī, 166	Per. *qabūlī* (from Ar. *qabūl*—acceptable)—accepted, admitted. Generally in Per. it means a dish of food resembling *khicṛī*.
Kamāna, 173	Per. *kamān*—bow.
Kāgaja, 8	Per. *kāgaz*—paper *cf. kāgada* where *z.* > *d.* just as in *gudarata*.
Kirica, 498	Per. *kirij*—a slice, a segment.
Kulaha, 168	Per. *kulah* (contracted from *kulāh*), T. D. uses it for a bird's cap to cover its eyes.
Kūra, 114	Per. *kūr*—blind ; blind in a moral sense, hence Aw. ignorant, idiot.
Kotala, 236	Per. *kutal*—a led horse for the parade, hence in Aw. a spare horse led by the string (*o* for *u* is probably the same as in Pkt. *pothī* < *pustikā* or Pali *pāmokkha* < *pramukha* explained from *Vṛddhi* forms).
Khabara, 123, *Khabari*, 78.	Ar. *khabar*—news, notice, care.
Khuārū, 276 ...	Per. *khwār*—contemptible, wretched.
Gaca, 97, 452 ...	Per. *gac*—plaster, mortar.
Ganī, 16 ...	Ar. *ganī*—free from want, rich.
Garadani, 229 ...	Per. *gardan*—neck.
Garība, 15, 16 ...	Ar. *garīb* (from *garb*—to become distant)—poor, destitute.
Garībanewājū, 10 ...	Per. *garībnawāz*—caresser of the poor.
Gudarata, 251 ...	Per. *guzar*—pass, ford, thence Aw. forms a participle.
Gumāna, 467 ...	Per. *gumān*—pride, doubt, distrust.
Gumānī, 300 ...	Per. *gumānī*—proud, vain, distrustful.

Caugānā, 382 ...	Per. *caugān*—a plain; the game resembling hockey, but played on horseback and hence like polo also.
Jamāta, 44, 77 ...	Ar. *jamā*,—a collection, gathering, plural *jamā't*—collections. T. D. uses the word as singular.
Jahāja, 243, *jahāju*, 191, 217.	Ar. *jahāz*—a ship (*jihāz*—however, means dowry).
Jahānā, 4 ...	Per. *jahān* (old Per. gehān)—world.
Jinisa, 44, 432 ...	Ar. *jins*—kind, species.
Jīna, 126, 133 ...	Per. *zīn*—saddle.
Tarakasa, 231 ...	Per. *tarkash*—quiver.
Tājī, 317 ...	Per. *tāzī*—invader; hunting-dog.
Darabāra, 378 ...	Per. *darbār*—court, audience.
Dāgē, 229 ...	Per. *dāg*—a mark, spot, brand; Aw. makes a participle—branded.
Naphīra, 408 ...	Per. *nafīr*—a kind of trumpet.
Naphīrī, 389 ...	Per. *nafīrī*—a kind of trumpet.
Nirajosu, 235 ...	Skt. prefix *nir*+Per. *josh*—without excitement, *i. e.* truly.
Nisāna, 77, 128, *nisānā*, 68,112,125.	Per. *nishān*—mark, sign, banner. colours; T. D. uses it invariably in the sense of military musical instruments.
Newājā, 255, *newājī* 273, *newājē*, 15.	Per. *nawāz* (*nawākhatan*—to caress.) —caresser, thence caressed.
Parawānā, 74 ...	Per. *Parwānā* (Skt. *pramāṇa*)—warrant, authority, sanction.
Palaka, 152,212, *palakanhi*, 100.	Per. *palak*—eyelid, hence in Aw., twinkling of an eye also.
Pirojā, 123 ...	Per. *fīrozā*—a turquoise (the stone which brings good fortune), *cf.* Hindi pirojā—an ointment chiefly efficacious in healing old wounds.

Poca, 5, 261, *pocu*, 269, *pocū*.	Per. *pūc*—empty, worthless (for *o* in place of *ū* vide supra note on *kotala*).
Phar̥ākа, 453 ...	Ar. *farq*—distance, thence in Aw. adj. *pharāka*—distant; with space in between.
Phauja, 401,408 ...	Ar. *fauj*—a crowd, an army.
Bakasīsa, 129 ...	Per. *bakhshīsh*—a present or pecuniary gratuity.
Bajāja, 453 ...	Ar. *bazzāz* (vulgar *bazāz*)—draper.
Bajāra, 93, *bajāru* 148, *bajārū*, 126,453, *bājāra*, 453.	Per. *bāzār* (old per. *abā*—provisions.+ *zār*—place)—market; the form *bājāra* used only once and that also *metri causa*.
Badalē, 498 ...	Ar. *badal*—change, exchange.
Bandīkhānā, 414 ...	Per. (*bandī* — prisoner + *khāna*—house) hence prison-house.
Barajora, 274 ...	(Skt. *vara*—good, strong. Per. *zor*—force) hence forcibly; *cf.* *Braj*—*barajorī kari morī bahiyā etc.*
Barābari, 118, 478...	Per. *barābarī*—level, par, equality.
Bāga 21, *bāgā* 23, *bāganha*, 190.	Per. *bāg*—garden.
Bāja, 115, *bāju* 168, *barabāja*, 218, *bhaya-khaga-bājaḥ* 295, *bājū*, 247.	Per. *bāz*—falcon; *bara* (Skt. *vara*)+ *bāz*=*barabāja*—good falcon; this compound indicates the extent of the assimilation of a loan-word.
Bājīgara, 383 ...	Per. *bāzīgar* (*bāz*—to play, hence *bāzī*—play and hence)—one who exhibits marvellous feats.
Bidā, 26, 144, 281 .	Ar. *widā'*—farewell.
Becārā, 364 .	Per. *bī*—(without) + *cāra* (remedy) *i.e.* remedyless, helpless.
Bebākī or *bibākī* 15.	Per. *bī*—without+Ar. *bāqī*—remainder hence, whole payment leaving no remainder.

Behālū, 282, *bihāla*, 428, *bihālā*, 394	Per. *bī*—without+Ar. *ḥāl*—condition, circumstance, hence ill-circumstanced. *N.B.*—In all these compounds with *bī*—the prefix is probably (Skt. *vi-*) Pkt. *bi-* and not the Persian *bī-*
Majūrī, 197 ..	Per. *muzdūr*—labourer and hence *muzdūrī*—bodily labour or wages, hire etc.
Masakharī, 483 ..	Ar. *maskhara*—jester, thence Aw. *maskharī*—jest, humour, *cf.* Per. *maskhargī* in the same sense.
Rajāī, 172, 175, 196, 198, 225	Ar. *razā*—pleasure, will, approval.
Rukha, 30, 105 ...	Per. *rukh*—face, countenance.
Lāyaka, 31, 158 ...	Ar. *lāyaq*—fit, capable, worthy.
Sajāī, 165 ...	Per. *sazā*—punishment *cf.* modern Aw. *sajāi.*
Sarāpha, 453 ...	Ar. *sarrāf* (vulgar *sarāf*)—a money-lender, a banker, shroff.
Sahī, 42, 313, 476, 484	Ar. *sahīh*—correct, sound, hence a noun—signature, sign, token, attestation.
Sahanāī, 113, 148 ...	Per. *shahnā* and *shahnāī*—a clarion, *cf.* also Per. *shāhnāi*—a military trumpet.
Sāja, 127, 139; *o sāju* 144, 149, *ku-sāju*, 173.	Per. *sāz*—making ready, preparation (Skt. *sajja* and *sajjana* do not exactly answer this sense); *ku*—Skt. prefix-bad.
Sādē, 243 ...	Per. *sāda*—simple, pure, white.
Sāhiba, 10, 17, *sāhibahī*, 262, *su-sāhiba*, 16, *su-sāhibu* 273, *susāhibahī*, 274	Ar. *sāhab* (from *sahab*—to associate hence)—one endowed with, master, Lord. Skt. *su*—good, hence *susāhiba*,—good master.

Siratāja, 142	Per. *sartāja* (lit. crown of the head), chief, leader.
Supetī, 152	Per. *sapēdī* or *safēdī*—whiteness, the *su-* for *sa-* is probably a wrong replacement of Per. *sa-* by the Skt. prefix *su-*; *t* for *d* is inexplicable.
Sora, 217, *sorā*, 401, *sorū*, 190.	Per. *shor*—noise, cry, exclamation.
Hawālē, 414	Per. *hawāla*—charge, custody.
Hālā 382, *hālu* 424	Ar. *hāl*—condition, circumstance.
Hunara, 454	Per. *hunar*—skill, ingenuity, art, knowledge.

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SYNTHETIC GRADATION IN INDIAN THOUGHT.

UMESHA MISHRA, M.A., KĀVYATĪRTHA,
Lecturer in Sanskrit.

I—DARÇANA.

Philosophy in India is not merely speculative. It has both theoretical as well as practical aspects. Scientific study to be worthy of its name, cannot afford to neglect either. Moreover, speculation, unless it is based on and has a counter-part in practical experience, is worse than useless. Such speculation cannot help anybody either here or in the world hereafter.

A reference to the use of the word 'Darçana'[1] for Philosophy in India, will show that a system of thought deserves to be called Darçana only when it gives us a true picture, fragmentary but faithful, of the whole Truth. The different Schools of Darçana, therefore, are the varied aspects of Truth viewed from different angles of vision. The connotation of 'Philosophy' is not exactly similiar but is likely to lead to confusion unless we bear in mind the fundamental difference between the two concepts. For want of a more appropriate word we are constrained to retain the term here, but we must not lose sight of the distinction noted above.

The origin of Philosophy in India is involved in great obscurity. It is very difficult to trace when and under what circumstances it assumed the organised shapes in which we find it now. It is obvious that these systematised forms cannot be natural. It evidently presupposes a stage

[1]This use of the word seems to be based on 'आत्मा वाऽरे द्रष्टव्यः...आत्मनो वाऽरे दर्शनेन...विज्ञानेनेदं सर्वं विदितम्' Bṛha. Upa. 2-4-5.

when there had been no system evolved. This is the period of the Upaniṣads[1] and allied literature, early Buddhistic as well as Jain. Here we find no arrangement in the ideas and views, which were the common property of the intellectual community of the country.[2] There being no system, the current ideas were assimilated in certain cases by different schools and formed the background of a distinct line of thinking in subsequent ages. As time went on such lines of thinking multiplied in number and began to develop each its individual character. Many of the ideas which were inseparably associated with certain systems in later times had then been in a floating condition.

II—THE SCHOOLS OF INDIAN PHILOSOPHY.

Now dealing with Indian philosophy it will not be out of point to consider the generally known divisions of Indian thought. We have been hearing much of the six systems. But what are these six systems? Here we find various opinions. As for instance: Haribhadra Sūri, a Jain writer, of about 1168 A.D.[3], means by six systems[4]: (1) Bauddha, (2) Naiyāyika, (3) Kāpila, (4) Jaina, (5) Vaiçeṣika, and (6) Jaiminīya. Another Jaina writer, Jinadatta Sūri, of about 1220 A.D.[5], mentions another kind of division under this head, namely[6]: (1) Jaina,

[1] *Cf.* Dr. A. B. Keith's—'The Sānkhya System', Ch. I.

[2] As for instance the problems of सर्वमस्ति, सर्वं सर्वत्रास्ति, सर्वदाऽस्ति and सर्वथाऽस्ति of the early Sarvatti Vādin sect of the Bauddhas seem to be the basis of the सत्कार्यवाद of the later Sānkhya.

[3] Dr. Satīça Candra's History of Indian Logic, p. 152.

[4] बौद्धं नैयायिकं साङ्ख्यं जैनं वैशेषिकं तथा। जैमिनीयञ्च नामानि दर्शनानाममून्यहो ॥—Ṣaḍdarçana Samuccaya, Verse 3, Choukhambā Ed.

[5] Dr. Satīça Candra's History of Indian Logic, p. 152.

[6] जैनं मैमांसकं बौद्धं साङ्ख्यं शैवञ्च नास्तिकम् । स्वस्वतर्कविभेदेन जानीयाद्दर्शनानि षट्—Viveka Vilāsa—manuscript belonging to the Govt. Sanskrit College, Saraswatībhavana, Benares.

(2) Maimāmsaka, (3) Bauddha, (4) Sāṅkhya, (5) Çaiva, and (6) Nāstika. The third Jaina philosopher, Maladhāri Çrī Rājaçekhara Sūri, of about 1348 A.D.[1], enumerates another kind of division[2], namely: (1) Jaina, (2) Sāṅkhya, (3) Jaiminīya, (4) Yauga (Çaiva), (5) Vaiçeṣika, and (6) Bauddha.

We now turn to the Brāhmanic writers. According to the son of the well-known commentator, Mallinātha, who must have flourished in the 14th cen.[3], Ṣaḍdarçana includes[4] (1) Pāṇini, (2) Jaimini, (3) Vyāsa, (4) Kapila, (5) Akṣapāda, and (6) Kaṇāda. Jayanta Bhaṭṭa, who is called an old logician—*Jarannaiyāyika*[5], and who must have flourished between the 9th and the 11th centuries, A.D.,[6] mentions that the *Saṭtarkī* (Ṣaḍdarçana)[7] includes the following six systems, namely: (1) Sāṅkhya, (2) Ārhata, (3) Bauddha, (4) Cārvāka, (5) Vaiçeṣika, and (6) Nyāya. In the Hayaçīrṣa—pañcarātra, a Brāhmanic work, supposed to have been introduced in Bengal by Rājā Ballāla Sena (about 1158-1170) as well as in the Gurugītā of the Viçvasāra tantra, the six systems[8] constitute the following: (1) Gautama, (2) Kaṇāda, (3) Kapila, (4) Patañjali, (5) Vyāsa, and (6) Jaiminī. The compiler of the Sarvamata Sangraha, divides the entire

[1] Dr. Vidyābhuṣaṇa's History of Indian Logic, p. 153.

[2] जैनं साङ्ख्यं जैमिनीयं यैागं वैशेषिकं तथा। सौगतं दर्शनान्येवं नास्तिकं तु न दर्शनम्—Ṣaḍdarçana Samuccaya, p. 1, Verse 4. Crī Yaçovijaya Jaina Granthamālā, Benares Ed. The last portion of this kārikā seems to be an attack on Jinadatta's taking Nāstika to be one of the systems.

[3] Dr. Vidyābhūṣaṇa's History of Indian Logic, p. 380.

[4] पाणिनेर्जैमिनेश्चैव व्यासस्य कपिलस्य च। अक्षपादस्य कणादस्य... in his com. on the Pratāparuda—Yaçobhūṣaṇa of Vidyādhara.

[5] Gaṅgeçopādhyāya—Nyāya Cintāmaṇi, Upamānakhaṇḍa p. 61. Society Ed.

[6] Dr. Vidyābhūṣaṇa's History of Indian Logic, p. 147.

[7] Nyāya mañjarī, Vol. I. p. 4, Vizianagram Sanskrit Series, Benares, Ed.

[8] गौतमस्य कणादस्य कपिलस्य पतञ्जलेः। व्यासस्य जैमिनेश्चापि दर्शनानि षडेव हि—quoted from Dr. Vidyābhūṣaṇa's History of Indian Logic, p. 153, ftn. 3.

field of Indian philosophy into two main heads,[1] namely: Vaidika and Avaidika. The former he again divides into three systems: (1) Mīmāṅsā, (2) Sāṅkhya, and (3) Tarka; while the latter into (1) Bauddha, (2) Ārhata, and (3) Lokāyata. Thus in all, there are six schools. Mahāmahopādhyāya Bhīmācārya in his Nyāyakoṣa, on 'Darçana'[2] tells us that there are only six prominent Āstika or orthodox schools of Darçana, which he enumerates thus: (1) Sāṅkhya, (2) Pātañjala, (3) Pūrva Mīmāṅsā, (4) Uttara Mīmāṅsā, (5) Tarka, and (6) Nyāya. By 'Tarka' he means 'Vaiçeṣika'. He also quotes in his notes thereon a line[3] to support what he has said. Later on, he talks of six Nāstika (non-orthodox) systems[4]. They are: (1) Cārvāka, the four schools of Bauddha philosophy, namely: (2) Mādhyamika, (3) Yogācāra, (4) Sautrāntika, (5) Vaibhāṣika, and (6) Digambara (one of the Jaina schools); and he mentions 'Vācaspatyakoṣa' which has included Māyāvāda Vedānta under the Yogācāra.

Besides these six systems, there are references, and even descriptive accounts of other varieties. As for instance, Mādhavācārya, in his Sarvadarçana Saṅgraha, considers the following schools[5] and sums up the characteristic doctrines of each: (1) Cārvāka, (2) Bauddha, (3) Ārhata, (4) Rāmānuja, (5) Pūrṇaprajña, (6) Nakuliça, (7) Pāçupata, (8) Çaiva, (9) Pratyabhijñā, (10) Raseçvara, (11) Aulūkya, (12) Akṣapāda, (13) Jaimini, (14) Pāṇini, (15) Sāṅkhya, (16) Pātañjala, and (17) Çaṅkara. The Sarvasiddhānta Sangraha[6]

[1] इह हि द्विविधानि विचारशास्त्राणि वैदिकावैदिकभेदात् । तानि च प्रत्येकं त्रिविधानि मीमांसासाङ्ख्यतर्कभेदात बौद्धार्हतलोकायतभेदाच्च । तत्राद्यत्रिकं वेदमूलत्वात् वैदिकम् । अपरत्रिकं बुद्धक्षपणकबृहस्पतिविरचितवेदाभासमूलत्वादवैदिकमिति । एवं षड्दर्शनानि—Sarvamatasaṅgraha, Trivandrum Sanskrit series, Travancore, 1918, pp. 14-15.

[2] Nyāyakoṣa, Bombay Sanskrit series Ed., 1893. pp. 317-18.

[3] द्वौ योगौ द्वे च मीमांसे द्वौ तर्काविति षट् बुधाः Ibid, ftn. 2.

[4] Ibid, pp. 371-72.

[5] Sarvadarçana Sangraha, Ānandāçrama Sanskrit Series, Poona.

[6] Published by M. Rangācārya, M.A., Madras.

attributed to Çaṅkarācārya enumerates another classification: (1) Lokāyatika, (2) Ārhata, (3) Bauddha, (wherein he includes all the four well known schools), (4) Vaiçeṣika, (5) Nyāya, (6) Mīmānsā (both schools—attributed to Prabhākara and Kumārila), (7) Sāṅkhya, (8) Patañjali, (9) Veda Vyāsa, and (10) Vedānta. Madhusūdana Sarsvatī, in his Prasthānabheda,[1] which forms a part of his commentary on Puṣpadanta's Mahimnastotra, and Guṇaratna Sūri,[2] in his commentary on the Ṣaḍdarçana Samuccaya of Haribhadra Sūri, mention several more. Guṇaratna observes, however, that there are no less than 360 or more lines of thought in Indian philosophy.

III—SEARCH AFTER TRUTH.

The inquirer after truth, hearing of so many different views, finds himself unable to understand the exact nature of the Truth. He approaches the Çrutis, which he believes to be the only infalliable source of Right Knowledge. He finds the right answer there. He learns from them the true nature of the Self, as described in the following: 'स वा एष पुरुषोऽन्नरसमयः' (Tai. Upa. 2. 1.); 'अन्योऽन्तर आत्मा प्राणमयः' (Ibid, 2. 2.); 'अन्योऽन्तर आत्मा विज्ञानमयः' (Ibid, 2. 4.); 'अन्योऽन्तर आत्माऽऽनन्दमयः' (Ibid, 2. 5.); 'एकमेवाद्वितीयम्' (Chā. Upa. 6. 2. 1.) etc. Had he had full faith in the words of the Çrutis, he would have at once got the illumination needed[3]. But as a human being, he is beset with doubts and wrong notions, which stand in the way of his immediate conviction. He then sets about collecting arguments in support of what he has heard from the Çrutis. This stage of reasoning, as based upon the premises, supplied by the Çrutis, is known as ***Manana.***

[1] Prasthānabheda, published by the Vāṇīvilāsa Press, Srirangam.

[2] L. Suali's Edition. Bibliotheca Indica, Introduction, pp. 19-21.

[3] श्रद्धावान् लभते ज्ञानम्—Bhagavad Gītā 4.39.

This is what speculative philosophy in India attempts to represent[1]. But mere speculation cannot reach the truth. It seems quite possible that the conclusions arrived at through speculation, *i.e.* मनन, might be overthrown at any moment by counter—reasonings of a stronger nature[2]. Examples of such supersession abound in both science and philosophy. The inquirer cannot rely upon this. It is necessary, therefore, to verify his rational conclusion through practical experiments; just as in geometry demonstration is supplemented by experimentation. This practical verification is reached through निदिध्यासन—contemplation[3]. The conclusions of the previous stage are hereby realised as truth and are unassailable. These are the steps leading to the direct perception of truth[4].

[1] श्रुतस्य परीक्षा न्यायेनैवावस्थापनं यामाहुर्मननमिति । सा चान्वीक्षिक्यामायतते—N. V. T., p. 49. Vizianagram series. That आन्वीक्षिकी is here used in the sense of 'Darçana'—'philosophy'.

[2] इतश्च नागमगम्येऽर्थे केवलेन तर्केण प्रत्यवस्थातव्यम्...तथा हि कैश्चिदभियुक्तैर्यत्नेनोत्प्रेक्षितास्तर्का अभियुक्ततरैरन्यैराभास्यमाना दृश्यन्ते । तैरप्युत्प्रेक्षिताः सन्तस्ततोऽन्यैराभास्यन्त इति न प्रतिष्ठितत्वं तर्काणां शक्यमाश्रयितुं पुरुषमतिवैरूप्यात्—Cañkara Bhāṣya on Brahma Sūtra 2. 1. 11.

(*ii*) यत्नेनानुमितोऽप्यर्थः कुशलैरनुमातृभिः । अभियुक्ततरैरन्यैरन्यथैवोपपाद्यते

—Bhartṛhari's Vākyapadīya. 1.34.

(*iii*) नो खलु दिङ्मूढः सहस्रेणाप्यनुमानैर्विपर्ययसंस्कारमपनयति—N. V. T., p. 49.

(*iv*) Kaṭhopaniṣad, Cañkara Bhāṣya, I. 2.8.

[3] आत्मा वाऽरे द्रष्टव्यः श्रोतव्यो मन्तव्यो निदिध्यासितव्यः—Bṛ. U. 2.4.5.

[4] (*i*) श्रोतव्यः श्रुतिवाक्येभ्यो मन्तव्यश्चोपपत्तिभिः ।
मत्वा च सततं ध्येय एते दर्शनहेतवः—quoted from the Introduction of Sā. Pra. Bhā. by Vijñānabhikṣu.

(*ii*) श्रुतेः श्रुत्वाऽऽत्मानं तदनु समनुक्रान्तवपुषो-
विनिश्चित्य न्यायादथ विहितहेयव्यतिकरम् ।
उपासीत श्रुत्वा शमदमविरामैकविभवो-
भवोच्छित्त्यै चित्तप्रणिधिविहितैर्योगविधिभिः ॥

—Ātmatattvaviveka, p. 131. Jībānanda's Ed.

These three factors have always been recognised in Indian Philosophy. All the Indian systems of thought, for instance, take their data from the Vaidika sources and build upon them the conclusions through rational arguments. They appeal to Yoga or निदिध्यासन for their verification[1]. This would seem to involve a kind of synthesis between the three *Pramāṇas*—instruments of right knowledge, namely: Āgama or Çābda, Anumāna (inference), and Pratyakṣa (direct perception), which seem to represent श्रवण, मनन, and निदिध्यासन respectively[2].

Before we proceed to find out how the different systems in India have originated, it would be better to start with a clear consciousness as to the starting point and goal of these systems. It is held that दुःखनिवृत्ति—removal of Pain is the underlying common motive of the entire creation. No one would like to have things which he dislikes. This is the end towards which every conscious and rational movement tends. Philosophical enquiry, therefore, presupposes the stage where Pain is felt, and naturally it aims at its absolute cessation.

Here the question arises: The goal and the starting—point being common, why do we find so many different views? The answer is quite simple. It is due to difference in the intellectual equipments of the enquirer. Philosophy, in India, is just like a stream taking its rise from the mountain top, flowing successively through several valleys and falling into the great ocean. Now the same stream, *e. g.* the Brahmaputra,[3] while passing through one valley to

[1] Vaiçeṣika Sūtra 6. 2. 16.; Nyāyabhāṣya on N. S. 4. 2. 2.; Sāṅkhyapravacanabhāṣya, ch. VI. 24-31.; Caṅkarabhāṣya on Brahma Sūtra 2. 1. 3.; Vedāntasāra, pp. 146-154. Jibānanda's Ed.; Nyāyavārtika-tātparyaṭikā, p. 49; Nyāya Sāra of Bhāsarvajña pp. 39-40, Society Ed.

The case of Mīmāṅsā, which repudiates Yoga, would appear to be an exception, but a deeper thinking would show that this is not so.

[2] *Cf.* Nyāyavārtika-tātparyaṭikā, p. 60.

[3] A river in the north-east India.

the other, has a particular shape, current, and sometimes name too, which begin to change as it proceeds onwards. If any one takes a photograph of it, in its passage through one valley and then again another while it passes through another and so on, he will have different pictures, though all of them will represent the same individual river; and a man, who has not seen the stream from one end to the other, can hardly assure himself that these photographs are of the same river.

Similarly, though all aim at the same goal yet because of the varieties of their predispositions and capacities (Adhikāra), the single path appears as so many different paths to them.

Or we may describe the final goal of Indian thought on the analogy of the *Arundhatī* star [1]. When the child asks the mother, 'where is the Arundhatī?', the mother, at once, directs its gaze towards the sky. Thereupon, she points to a bigger star near the Arundhatī, for she knows well that the star in question being very small, it is not possible for the child to find it at once. But when the child has acquired sufficient power of observation, it finds out the star easily.

In the same way, the supreme goal is so subtle that the Ṛṣīs—the seers of truth—thought that it would be quite impossible for all to grasp the line of thought which directly leads to it. [2] Therefore, for the good of the people, they constructed so many steps, which if gradually followed would lead to the goal. People, not following these paths, are likely to be led astray and never to

[1] *Cf.* Nṛsinha Sarasvatī's com. on the Vedāntasāra, p. 106, Jībānanda's son's Ed.

[2] (i) बहिर्विषयप्रवणानामापाततः पुरुषार्थे प्रवेशो न सम्भवति— Madhusūdana's Prasthānabheda, p. 19.

(ii) एकदा परसूक्ष्मे प्रवेशासम्भवात्—Vijñānabhikṣu, Introduction to the Sā. Pra. Bhā., p. 2; Jībānanda's Ed.

find the right path and the truth.[1] So did Kṣemarāja, in his Pratyabhījñahṛdaya[2] say clearly that all the systems are so many artificial stages of the progress of the Ātman, just like an actor assuming various roles till the end of the play; or we may liken it to the reaching of the mountain top with a certain number of steps which must be crossed.[3]

This shows that there is not only a mutual harmony but even a gradation in ascending order in the various systems of Indian thought; and every system is consistent within its limits. For in Nature there is unity amidst diversity. The world is governed by law, and no fact can be inconsistent with any other fact, however opposed the two may appear to be. This is true not only of philosophy, but on close analysis, it will be evident in every branch of knowledge in India.

Now the question is: if all the systems are equally true, how is it that the propounders of a particular system repudiate the validity of the other sister systems? Even accepting the synthetic view, it is urged, it would have been plausible for the highest system alone to contradict the other views, as Çaṅkarācārya has done in the Brahma Sūtra Bhāṣya, Adhyāya II, Pādas 1-2; but as a matter of fact we find all the systems speaking against one another. The answer seems to be clear: it is so, because each system wants to keep its own *Adhikārīs* (those who are qualified for the stage represented by that system) firm in their respective positions (Adhikāras). Else they are likely to be

[1] तेषां तात्पर्य्यमबुद्ध्वा वेदविरुद्धेऽप्यर्थे तात्पर्य्यमुत्प्रेक्षमाणास्तन्मतमेवोपादेयत्वेन गृह्णन्तो जना नानापथजुषो भवन्ति—Madhusūdana Sarasvatī's Prasthānabheda, p. 19. Vāṇivilāsa Ed.

[2] Pratyabhijñāhṛdaya, pp. 16-18, Kashmir Sanskrit Series, Ed.

[3] Saṅkṣepaçārīraka, II., 60-61; Nṛsinha Sarasvatī's com. on the Vedāntasāra, pp. 106-107, Jībananda's son's Ed.

entangled in a maze and thrown off their track.[1] Moreover, if we closely follow the texts, we find that the higher systems do not really deny the '*Relative*' truth of the lower systems. For instance, the Vedānta holds that though the Highest Truth is not to be found in the Sāṅkhya, the Yoga, or the Pāçupata, they have each its own sphere of usefulness which remains undisturbed.[2] It is clear from this that as far as the orthodox school is concerned, the '*Highest Truth*' lies with the Vedānta of Çaṅkara, while only the '*Relative Truth*' can be had from the other sister systems.

IV.—A STUDY OF THE INNER HARMONY OF THE SYSTEMS.

We have seen that the systems of philosohpy in India are numerous. As it would not be possible to deal with them all within the limit of this paper, I should like to select a few from amongst them and take them up for a study of their inner harmony. It would be better for our practical purposes to consider some of the systems of philosophy and to see if we

[1] *Cf.* Prasthānabheda, Ibid.

[2] (i) शारीरके च साङ्ख्योक्ततत्वानामब्रह्मात्मकतामात्रं निराकृतं न स्वरूपम् । योगपाशुपतयोश्चेश्वरस्य केवलनिमित्तकारणता परावरतत्वविपरीतकल्पना वेदबहिष्कृताचारो निराकृतो न योगस्वरूपं पशुपतिस्वरूपञ्च । अतः 'साङ्ख्यं योगः पञ्चरात्रं वेदाः पाशुपतं तथा । आत्मप्रमाणान्येतानि न हन्तव्यानि हेतुभिः' इति तत्तदभिहिततत्तत्स्वरूपमात्रमङ्गीकार्य्यम्—Cribhāṣya. II. 2. 42. p. 512, Bombay Sanskrit Series Ed.

(ii) प्रकृतेर्गुणसम्मूढाः सज्जन्ते गुणकर्मसु । तानकृत्स्नविदो मन्दान् कृत्स्नविन्न विचालयेदिति गीतायां (III. 29.) कर्त्तृत्वाभिमानिनस्तार्किकस्याकृत्स्नवित्व-मेव कृत्स्नवित्साङ्ख्यापेक्षयोक्तम् । न तु सर्वथैवाज्ञत्वमिति...न्यायवैशेषिकोक्तज्ञानस्य परमार्थभूमौ बाधितत्वाच्च । न चैतावता न्यायाद्यप्रामाण्यम् etc. Vijñānabhikṣu's Intro. to Sā. Pra. Bhā. p. 3.

(iii) न चोभयोः (साङ्ख्यवेदान्तयोः) मिथो विरोधादेकत्र सिद्धान्तत्वानुपपत्तिः । पूर्वोत्तरभूमिकारूपेणाविरोधस्य वक्ष्यमाणत्वादिति—Rāmatīrtha's com. on Sanṣkepaçārīraka, II. 56.

can discover in them unity of purpose and in that light arrange them in a progressive series.

a.—The Common—sense view.

The removal of Pain (दुःखनिवृत्ति), it has been pointed out, is the common aim of all the schools and the stage where it is felt is the starting-point. This starting—point seems to be the stage of the common, or more accurately, vulgar people, or as the Buddhists call them *Puthujjana*. At this stage, truly speaking, there is no reason. They do not believe in things which they do not directly perceive through the senses. And consequently they have no faith in the Ātman as something distinct from the body which is a peculiar amalgamation of the four elements, namely: earth, water, fire, and air. Creation to them is due to chance. Their journey terminates, therefore, with the end of this body. There is nothing left after death. The feelings of Pain that they experience at times in life end when the body, which is the seat of these feelings, comes to an end. In other words, they find their goal (दुःखनिवृत्ति) reached in death.[1] It is needless to say that the exponents of this 'Common—sense view' quote Çrutis[2] (of course as a strengthening example only) as well as their daily experiences (as expressed in judgments) in defence of their position.

It is thus clear that they lay stress on this body[3] with which they identify the Ātman. Their supreme aim, *i. e.* (दुःखनिवृत्ति) is realised in death beyond which they cannot look. Here ends the first stage of our long journey.

b.—The Nyaya-Vaicesika or Realistic view.

When we become a little more intelligent, we feel

[1] *Cf.* My article on 'Cārvāka Darçana'—published by the Belvedere Press, Allahabad.

[2] स वा एष पुरुषोऽन्नरसमयः—Tai. Upa., 2. 1.

[3] चैतन्यविशिष्टं शरीरमात्मा—Pratyabhijñāhṛdaya, p. 16.

that the above ideas no longer satisfy us. We do believe that whatever we see in the world around us has its real existence; but apart from these there is something else which seems to be of a different type. The feelings of pleasure and pain that we have, cannot be logically assigned to the body but to something else as is apparent from our experiences expressed in judgments—'I am happy', 'I possess the knowledge of this book etc.' We also feel that the objects about us to which we cling with so much tenacity during life are perishable and are the causes of pain in the long run. It is an instinct that a man, or for the matter of that every animal, abhors pain and seeks to discover its remedy. Hence in this stage we feel naturally inclined to approach the Çrutis[1] as well as the illuminated teachers[2], whose knowledge of things is clear and immediate. For we can no longer satisfy ourselves with the conviction that death will terminate our pain, inasmuch as the Self (Ātman) which alone feels the pain is believed to survive physical death.

There we are told that the knowledge of the true nature of the objects (Padārthas)[3] of the universe will bring to us the 'Everlasting peace.' Upon this basis we proceed to argue and then verify our conclusions by experiments, that is, *Nididhyāsana* or yoga. This whole process takes a long time. But as the duration of a man's life is very short it becomes impossible generally to reach the gnosis in a single birth. Nevertheless whatever is done in a life is not at all lost. It sticks to us and forms the nucleus round which the developments of the next life will arrange themselves. Really we start in the next life where we stopped in the past, so that the thread of continuity remains

[1] Tai. Upa., 2. 5.

[2] Akṣapāda and Kaṇāda.

[3] N. S. and Bhā. I. 1. 2. ; V. S. I., 1. 4.

unbroken. Thus we proceed till we come to the end of the second stage of our journey.

It is clear from this that there is something which survives the dissolution of the physical body. Then the question is : how is the surviving entity carried on to a fresh body after death? Just after death by the instrumentality of *Adrṣṭa* a motion is produced in the various Aṇus and they gradually (*i. e.* through the process of Dvyaṇuka etc.) build up a gross-body, though subtler than the one left dead. It, being subtle, is supersensuous. It is this body which conveys the Manas to another body where the Self (Ātman) is to reap the fruits of its past deeds. Hence it is known as the *Ātivāhika* body [1].

Here then is a clear proof that this system has advanced a step higher in accepting a subtler body, though it is made of the gross elements, leading the Manas to another body. Besides this we have also referred to the eternal character, that is, the '*Sat*' aspect of an entity which we have att his stage formed to be the seat of feelings etc., and which is quite different from the body. This something is, of course, the Ātman.

After we have known the true nature of the various categories (Padārthas), the 'faults' (Doṣa) disappears. It is followed by the disappearance of 'action' (Pravṛtti), and then the cessation of birth, the cause of pain.[2] There being no cause, the effect, that is, pain, will never reappear. In other words, we realise here our aim (दुःखनिवृत्ति) with which we started. Here this system stops.

But we must bear in mind that the Nyāya-Vaiçeṣika has admitted the Paramāṇus of earth, air, water and fire, Ākāça, Kāla, Dik and Ātmās and Manāmsi as eternal elements. They will ever remain. So

[1] Nyāyakandalī p., 310, Vizianagram Sanskrit Series, Ed.
[2] Nyāya Sūtra I 1. 2.

they continue to exist when the Ātman has attained Mokṣa.[1]

c.—The Sāṅkhya Stage.

But really our progress does not stop here. There are subtler elements behind these. The next school *i. e.* Sāṅkhya starts with the eternal elements of the Nyāya-Vaiçeṣika. The causal analysis of Sāṅkhya leads gradually to Prakṛti, which is Pure Matter and consists of extremely fine composites, called Guṇas in a state of equilibrium. If we study the classification of the Tattvas of Sāṅkhya, we shall find that we are lifted up step by step from the grosser to the more subtle elements until we reach the Highest Level. The Paramāṇus, which were supposed to be indivisible, are shown here as products of the Five Tanmātrās, which are again the products of the Tāmas aspect of Ahaṅkāra[2]. Ākāça, Kāla and Dik, which were all-pervading (Vibhu) and eternal with Nyāya-Vaiçeṣika, are reduced to *one divisible element*, that is, Ākāça[3], which is produced from 'Çabda Tanmātrā'[4]. So we see that the so-called 'eternal' elements of Nyāya-Vaiçeṣika are reduced into still subtler elements in Sāṅkhya.

The Ātman of Nyāya-Vaiçeṣika, as the seat of knowledge, desire, will, etc., is really the Mahat Tattva or Buddhi of Sāṅkhya. Every element at this stage is known to consist of the three Guṇas—viz.. Sattva, Rajas, and Tamas. As long as the Tamas and Rajas elements

[1] The Ātman is free from its Viçeṣaguṇas and exists in its '*Svarūpa*' in Mokṣa. *cf.* सर्वगुणवियुक्तस्यात्मनः स्वरूपेणावस्थानम्'—Guṇaratna's com. on Ṣaḍdarçanasamuccaya, pp. 72-73.; 'तदेवं धिषणादीनां नवानामपि मूलतः। गुणानामात्मनो ध्वंसः सोऽपवर्गः प्रकीर्त्तितः'—Jayasinha Suri's com. on Nyāya Sāra, p. 283, Society Ed.

[2] Tattva Kumudi on Sāṅkhya Kārikā, 22.

[3] Sāṅkhya Sūtra II., 2. 12.

[4] Sāṅkhya Kārikā, 22.

are present in the Self, that is Mahat, the existence of Ignorance and Pain is inevitable. The Right Knowledge and cessation of Pain which the Nyāya-Vaiçeṣika claims to have secured can, therefore, be only Relative. It is necessary, therefore, to get rid of these elements. The only remedy then is, according to Sāṅkhya, to obtain the discriminative knowledge (Viveka Buddhi) of the Vyakta (Manifested), the Avyakta (Unmainfested), and the Jña (Consciousness)[1].

On analysis the Vyakta is resolved into 23 aspects,[2] but the Avyakta and Jña are incapable of analysis—the one, because it is the equilibrium of all Guṇas and the other, because it is by nature immutable and transcendent. The true nature of these Tattvas has been discovered in order that Peace and everlasting दुःखनिवृत्ति may be secured.

Through the process of Çravaṇa, Manana, and Nididhyāsan we come to know their nature, when we find that the phenomena of mental life which are attributed to the Self on account of indiscrimination (अविवेक) belong really to the Mahat or Citta. Puruṣa is beyond the natural series and is the Principle of Intelligence. It is so closely associated with the Mahat that the confusion of one for the other is natural until the two are really separated off by discriminative knowledge. Puruṣa is a pure conscious entity.[3] It is like a pure crystal in front of a red flower which makes the colourless crystal look coloured and possess attributes.

The state reached by Discrimination is Purification or 'Kaivalya', wherein all kinds of pain cease to exist and Puruṣa becomes isolated.[4] It then beholds the

[1] Sā. Kā. 2.

[2] Tattva Koumudī on Sā. Kā. 3.

[3] Ibid, 19.

[4] Ibid, 19.

Prakṛti or 'the state of equilibrium' as an uninterested spectator (द्रष्टा).[1] It is clear from this 'Beholding' that Sattva is present there in its Purest form[2]. Due to the presence of this Sāttvika Buddhi (or Çuddha Sattva) which is multiple in number the One Transcendent Consciousness becomes as it were numerous. This is the only explanation of the multiplicity of Puruṣa. The state of Kaivalya represents on one hand the transcendence of Puruṣa and on the other the absolute purity of Citta or Sattva, which now is, of course, inactive.

It is apparent from the above that Sāṅkhya has advanced a step beyond Nyāya-Vaiçeṣika. It has established the 'cit' aspect of the Ātman and has reduced the number of eternal entities to two.

d.—Vedānta Stage.

Vedānta takes up the enquiry where Sāṅkhya had left it and seeks to resolve the Dualism of the latter into the unity of the Supreme Truth. It shows that Puruṣa must remain as it were divided, so long as it is associated with an Upādhi which is foreign to and other than itself. The Sāṅkhya stage recognised the 'Liṅga deha' of the Self and ended by destroying it or purifying it in the absolute manner. The so-called Kaivalya is only the cessation of the Liṅga. The Vedānta takes up the Purified Sattva of Sāṅkhya and shows that this too is verily a vesture of the True-self, though it is pure by nature, inasmuch as it is multiple. As such, it is the 'Causal body' (कारणशरीर) of the Jīva, and when reduced to Unity, it is the Causal body of God (Içvara). This is the 'Ānandamaya Koṣa' and though recognised as eternal in certain schools of Vedānta (*e. g.* Rāmānuja) as being the eternal associate of the Self, Çaṅkara seeks

[1] Sā. Kā. 65 and Yoga Sūtra, 1. 3. 4.
[2] Sā. Kā. 65: and T. Koumudi thereon.

to transcend it so that Absolute Unity may be realised. The process adopted is generally of 'Viveka', technically known as कोशविवेक, and sometimes of Laya too.

In any way the realisation of Supreme Truth as One ends in the Realisation of the Infinite Joy of Self-Delight. This too subsides and then the Absolute alone remains.

THEORY OF THE ORIGIN OF THE UNIVERSE.

e.—Materialistic View.

Similarly we may take up another problem,—the theory of the origin of the universe. We have seen that the Materialists hold that the universe is created from the fortuitous amalgamation of the four gross-elements.

f.—Nyāya-Vaiçeṣika View.

The representative of Nyāya-Vaiçeṣika view holds that the ultimate cause is eternal and the effects are occasional. Matter is atomic and effects do not pre-exist in their causes. The relation between the two is one of absolute difference (अत्यन्तभेद). This view corresponds to the Ārambha Vāda or Asatkārya Vāda.

g.—Sāṅkhya View.

Then comes the Sāṅkhya which holds that the universe is only a manifestation. That is to say, it existed as unmanifest in its cause (which has been reduced to unity now). Hence there is no absolute difference (अत्यन्तभेद) between the cause and its effect. It is impossible to produce a thing from a cause where it did not lie involved. Causation is simply explication or unfoldment. But there is some difference between the two also; so that the relation between the two is aptly described as भेद-सहिष्णु अभेद। This view corresponds to the Pariṇāma Vāda or the Satkārya Vāda.

h.—Vedānta View.

According to Vedānta School the universe is an illusory appearance, of the One Eternal Reality, viz. Brahman; that is, there is no भेद between the Brahman and the world. It must be noticed here that this school boldly denies the reality of the objective world while others have it in some form or another. Here we find the unity reached to which the earlier systems have been only tending.

Thus in brief we find that there is a synthesis in the ascending order among the systems of Indian thought. If closely studied one system will appear to follow another in natural order just like a corollary of a Geometrical proposition.

V.—A STUDY OF THE NON-ORTHODOX SYSTEMS.

We may conclude our brief survey with an illustration from the non-orthodox systems. We find that the Bauddha Darçana in its earlier stages was divided into a large number of schools; but its main schools[1], as recognised in later times, are: (1) Vaibhāṣika, (2) Sautrāntika, (3) Yogācāra, and (4) Mādhyamika.

i.—THE VAIBHĀṢIKA SCHOOL.

The Vaibhāṣika school holds that the world of our experience has an objective reality and that it is an object of perception and sometimes of inference also. It is independent of the Buddhi.

ii.—THE SAUTRĀNTIKA SCHOOL.

But the Sautrāntika holds that though the external world exists, its existence cannot be directly vouched for

[1]Guṇaratna's Com. on Ṣaḍdarçana Samuccaya p. 20.; Sarva Siddhānta Sangraha attributed to Caṅkara. p., 9-18.

by our senses, but that it is inferred from the multiple forms in which our consciousness, which is naturally formless and pure, presents itself. The 'doctrine of momentariness' both of external as well as mental phenomena is accepted by both.

Thus the real difference, between the two schools, both of which are equally realistic, consists in the attitude in which each looks at the order of external reality. The burden of emphasis appears to be shifting from the outer to the inner.

iii.—THE YOGĀCĀRA SCHOOL.

The Yogācāra school, however, denies the objective character of the world. It posits an infinite number of ideas each momentary and self-contained and seeks to account for the phenomena of experience by means of these[1]. It is due to Nescience (अविद्या) that we differentiate an Idea, which is by nature self-luminous and indivisible, into the complex of subject, object and consciousness. This system has done away with the external world altogether and seems to have retired more into the Inner Sanctuary of Absolute Truth.

iv.—THE MĀDHYAMIKA SCHOOL.

The finishing touch is given by the so-called Nihilistic or Mādhyamika school, which dispenses with the necessity of recognising the Vijñāna or Idea as well. Thus all traces of phenomenal experience, both objective and subjective, are effaced, and what is left behind is the Serene Depth of an Infinite Void. It is called शून्य in the sense that it is eternally free from everything with which our subjective or objective consciousness is acquainted: it is above the world, beyond the world and even permeating the world, though not defiled by

[1] Sarvasiddhanta Sangraha. Ch. VI.

it, as its abiding background. It is neither Positive, nor even Negative (as the word might seem to imply), nor both simultaneously, nor other than both, so that it is undefinable and in a sense has no 'character' (अलक्षणम्). The Mādhyamika explains the whole paraphernalia of cosmic experience from the stand-point of this Çūnya with the aid of Avidyā.

Studying the four systems in the order in which we have arranged them we find that there is a conscious attempt at gradual retirement from the external to the internal and from there into the Abyss of the Void which is the consummation sought for. The Doctrine of Momentariness is only a stepping stone to that of Universal Vacuity. Hence the conception of Nirvāṇa has received a fresh purging at every stage until it has reached its true significance in the Mādhyamika School, which is meant for the student of the highest *Adhikāra.*[1]

It is not possible to dwell here on the question of synthesis between the orthodox system and the Bauddha or the Jain. The systems run along parallel lines and aim at the same goal, though differently viewed. There is absolutely no contradiction between them, inasmuch as each being consistent with itself leads to the self-same destination. What we have said of the Bauddha or Jain Schools appears with equal force to the several branches of orthodox philosophy.

[1] Çribhāṣya II., 2. 30. pp. 495,12-15. Bombay Sanskrit Series Ed.

THE VṚṢĀKAPI HYMN.

ITS MEANING AND IMPORTANCE.

KSHETREŚACHANDRA CHAṬṬOPĀDHYĀYA, M. A.,
Lecturer in Sanskrit.

इन्द्राविष्णू नमस्कृत्य वार्षाकपं विचार्यते ।
सूर्यस्यैव स्तुतिर्यत्र मधुरोऽपि रसस्तथा ॥
प्रसङ्गेन यदुत्वञ्च पशोरत्र स्फुटीकृतम् ।
महानन्दः परं ब्रह्म प्रीयतां मत्प्रचेष्टया ॥

The tenth *maṇḍala* of the Ṛgveda (X.86) and the twentieth book of the Atharvaveda (X.126) contain a dialogue between Indra and his wife Indrāṇī over some offence of Vṛṣākapi. The hymn which records this dialogue is considered obscure and various interpretations have been proposed for explaining the story referred to here. Vṛṣākapi, a favourite of Indra, has offended Indrāṇī for which she is extremely angry and she tries to rouse the anger of Indra against him and threatens to punish him herself (if Indra does not move in the matter). European scholars have generally taken Vṛṣākapi to mean 'a monkey', or more precisely, 'strong ape or a male ape (Mannaffe)'. "V. Bradke considers the story a satire, in which under the names of Indra and Indrāṇī a certain prince and his wife are intended."[1] Similarly Oldenberg in his "Die Religion des Veda". (Third and Fourth Editions, p. 167). According to M. Bergaigne[2], Vṛṣākapi was a mythical sacrificer. Geldner[3]

[1] Macdonell's Vedic Mythology, p. 64.

[2] La Religion Vedique, II, 270—My information is taken from Griffith, Hymns of the Rigveda (Second Edition) II, p. 507 note.

[3] Vedische Studien, II, p. 23.

took the hymn as a humorous description of the domestic life of the gods. And Macdonell[1] considers the myth to have no general significance. But the late Lokamānya Tilak in his "Orion" (Chapter VII) has proposed an astronomical interpretation of the myth.

I shall attempt below a new interpretation of the hymn. I follow Roth in considering the Ṛgveda to be its own safest commentary. But as the Vṛṣākapi myth or the name *Vṛṣākapi* does not occur elsewhere it will be desirable to *start from the known* interpretation of the earliest Vedic interpreters and then try to see how far this hymn and the rest of the Ṛgveda support their explanation. The ultimate determining factor, of course, must be the Vedic texts themselves.

I shall have to discuss the entire hymn but in so doing I shall refer to the previous interpretations rather sparingly because otherwise I shall take up too much space. Scholars will kindly consider my interpretations on the basis of the texts I quote below and the discussions I can enter into here. This is the text of the hymn :—

वि हि सोतोरसृक्षत नेन्द्रं देवममंसत ।
यत्रामदद्वृषाकपिरर्यः पुष्टेषु मत्सखा विश्वस्मादिन्द्र उत्तरः ॥ १ ॥
परा हीन्द्र धावसि वृषाकपेरति व्यथिः ।
नो अह प्र विन्दस्यन्यत्र सोमपीतये विश्वस्मादिन्द्र उत्तरः ॥ २ ॥
किमयं त्वां वृषाकपिश्चकार हरितो मृगः ।
यस्मा इरस्यसीदु न्वर्यो वा पुष्टिमद्वसु विश्वस्मादिन्द्र उत्तरः ॥ ३ ॥
यमिमं त्वं वृषाकपिं प्रियमिन्द्राभिरक्षसि ।
श्वा न्वस्य जम्भिषदपि कर्णे वराहयुर्विश्वस्मादिन्द्र उत्तरः ॥ ४ ॥
प्रिया तष्टानि मे कपिर्व्यक्ता व्यदूदुषत् ।
शिरो न्वस्य राविषं न सुगं दुष्कृते भुवं विश्वस्मादिन्द्र उत्तरः ॥ ५ ॥
न मत्स्त्री सुभसत्तरा न सुयाशुतरा भुवत् ।
न मत्प्रतिच्यवीयसी न सक्थ्युद्यमीयसी विश्वस्मादिन्द्र उत्तरः ॥ ६ ॥

[1] Vedic Mythology, p. 64.

उवे अम्ब सुलाभिके यथेवाङ्ग भविष्यति ।
भसन्मे अम्ब सक्थि मे शिरो मे वीव हृष्यति विश्वस्मादिन्द्र उत्तरः ॥७॥
किं सुबाहो स्वङ्गुरे पृथुष्टो पृथुजाघने ।
किं शूरपत्नि नस्त्वमभ्यमीषि वृषाकपिं विश्वस्मादिन्द्र उत्तरः ॥ ८ ॥
अवीरामिव मामयं शरारुरभि मन्यते ।
उताहमस्मि वीरिणीन्द्रपत्नी मरुत्सखा विश्वस्मादिन्द्र उत्तरः ॥ ९ ॥
संहोत्रं स्म पुरा नारी समनं वाव गच्छति ।
वेधा ऋतस्य वीरिणीन्द्रपत्नी महीयते विश्वस्मादिन्द्र उत्तरः ॥ १० ॥
इन्द्राणीमासु नारिषु सुभगामहमश्रवम् ।
नह्यस्या अपरं चन जरसा मरते पतिर्विश्वस्मादिन्द्र उत्तरः ॥ ११ ॥
नाहमिन्द्राणि रारण सख्युर्वृषाकपेरृते ।
यस्येदमप्यं हविः प्रियं देवेषु गच्छति विश्वस्मादिन्द्र उत्तरः ॥ १२ ॥
वृषाकपायि रेवति सुपुत्र आदु सुस्नुषे ।
घसत्त इन्द्र उक्षणः प्रियं काचित्करं हविर्विश्वस्मादिन्द्र उत्तरः ॥१३॥
उक्ष्णो हि मे पञ्चदश साकं पचन्ति विंशतिम् ।
उताहमद्मि पीव इदुभा कुक्षी पृणन्ति मे विश्वस्मादिन्द्र उत्तरः ॥१४॥
वृषभो न तिग्मशृङ्गोऽन्तर्यूथेषु रोरुवत् ।
मन्थस्त इन्द्र शं हृदे यं ते सुनोति भावयुर्विश्वस्मादिन्द्र उत्तरः ॥१५॥
न सेशे यस्य रम्बतेऽन्तरा सक्थ्या३ कपृत् ।
सेदीशे यस्य रोमशं निषेदुषो विजृम्भते विश्वस्मादिन्द्र उत्तरः ॥१६॥
न सेशे यस्य रोमशं निषेदुषो विजृम्भते ।
सेदीशे यस्य रम्बतेऽन्तरा सक्थ्या३ कपृद्विश्वस्मादिन्द्र उत्तरः ॥१७॥
अयमिन्द्र वृषाकपिः परस्वन्तं हतं विदत् ।
असिं सूनां नवं चरुमादेधस्यान आचितं विश्वस्मादिन्द्र उत्तरः ॥१८॥
अयमेमि विचाकशद्विचिन्वन्दासमार्यम् ।
पिबामि पाकसुत्वनोऽभि धीरमचाकशं विश्वस्मादिन्द्र उत्तरः ॥१९॥
धन्व च यत्कृन्तत्रं च कति स्वित्ता वि योजना ।
नेदीयसो वृषाकपेऽस्तमेहि गृहाँ उप विश्वस्मादिन्द्र उत्तरः ॥२०॥
पुनरेहि वृषाकपे सुविता कल्पयावहै ।
य एषः स्वप्ननंशनोऽस्तमेषि पथा पुनर्विश्वस्मादिन्द्र उत्तरः ॥२१॥
यदुदञ्चो वृषाकपे गृहमिन्द्राजगन्तन ।
क्व१ स्य पुल्वघो मृगः कमगञ्जनयोपनो विश्वस्मादिन्द्र उत्तरः ॥२२॥
पर्शुर्ह नाम मानवी साकं ससूव विंशतिम् ।
भद्रं भल त्यस्या अभूद्यस्या उदरमामयद् विश्वस्मादिन्द्र उत्तरः ॥२३॥

Before beginning a rendering of the hymn I must settle what the word *Vṛṣākapi* means. European scholars, as I have just said, have taken it in the sense of '*male ape*', because *kapi* in the later literature regularly means an '*ape*'. But is it certain that the word had the same meaning in the Ṛgveda ? As it occurs in no other hymn the question is difficult to decide. Let us see if by passing *from the known to the unknown* any light could be obtained. First of all let us try this sense of '*ape*' in the hymn. At first sight, no difficulty confronts us. That Indrāṇī should be addressed as mother to a 'monkey' in verse 7 does not constitute any difficulty, for tamed animals are considered as children by householders. But it must be confessed that there is not a single expression in the hymn *positively* supporting the meaning of 'monkey' for *kapi*. On a closer study of the hymn we find at least one expression which goes against the equation *kapi*-monkey. Vṛṣākapi has been called पुल्वघो मृगः 'sinner beast' (Roth—'viel übles tuend'—a Bahuvrīhi compound between पुलु and अघ) or better 'dread beast' in verse 22. The 'sin' referred to cannot be the offence complained of by Indrāṇī in verse 5, *viz.*, the spoiling of her favourite things. For 'sin' would be much too strong a word for the offence; besides, that is only one offence, whereas Vṛṣākapi is called '*many*-sinned'. There is also the fact that after verse 17, we find Indrāṇī reconciled to Vṛṣākapi, so that we would not expect a connotation of reproach in a term used for Vṛṣākapi in verse 22. I therefore translate the word *pulvaghā* (with the same analysis as Roth's) by 'dread'. Gods are often called in praise 'dread' 'of terrible aspect' &c. We may therefore parallel the expression पुल्वघो मृगः by मृगो न भीमः in I. 154·2, said about Viṣṇu[1].

[1] Yāska (Nir. I. 20) has the following note on मृगो न भीमः कुचरः of I. 154·2 : भीमो बिभ्यत्यस्माद् भीष्मोऽप्येतस्मादेव । कुचर इति चरति

Grassmann[1] thinks that the objective *aghā* originally meant 'oppresive' (bedrängend, würgend). The meaning of 'terrible' is not therefore impossible for *pulvaghā*. A monkey can hardly be called a 'dread beast'. I think therefore that the equation *kapi*='monkey', in accordance with later usage, fails us here.

Let us now see if Yāska can give us any help. His note on the name Vṛṣākapi is अथ यद्रश्मिभिरभिप्रकम्पयन्नेति तद्वृषाकपिर्भवति वृषाकम्पनः . Yāska connects the word *kapi* with the root कम्प् 'to tremble'. But as no conjugational form or any other derivative of the root is found in the Ṛgveda, we may safely reject Yāska's explanation as one of his usual etymological fictions. But Śaunaka, the author of the Bṛhaddevatā, a work not far removed in time from Yāska, gives a more sensible interpretation, *viz.*, *kapi*=*kapila* ('tawnycoloured')[3].

In the Bṛhad-devatā (VII. 141), he thus enumerates the 'deities' of the hymn under discussion :

'वि हि' वार्षाकपं सूक्तम् असौ हि कपिलो वृषा ।
इन्द्रः प्रजापतिश्चैव विश्वस्मादिन्द्र उत्तरः ॥ [4]

कर्म कुत्सितम् Yāska feels that the last adjective is not complimentary to a god (according to the ideas of his times) and he continues अथ चेद्देवताभिधानं, कायं न चरतीति । Of course the second explanation is preferable on other grounds but Yāska's words show that it is possible to find gods described as 'dread animals'. That Vṛṣākapi is a god will be shown below.

[1] Wörterbuch Zum Rig-Veda, column 12.

[2] Grassmann in his Wörterbuch, 313 and 314, follows Yāska in deriving कपिः of the present hymn (X. 86. 5) from the root कम्प् but his reasons are not apparent to me.

[3] Grassmann (Wb. 313) derives *kapilá* from *kapì* giving it the etymological meaning of 'having the colour of the *kapì*=monkey'. But it is quite possible that *kapì* and *kapilà* are two forms of the same word like *hári* and *hárita* and 'tawny' may have been the original meaning of *kapì*. The monkey may have been called *kapì* because he had the tawny colour. Similarly the lion and the monkey were in later times called simply *harì*.

[4] Macdonell's rendering of the verse (H.O.S. Vol. 6, p. 288). " 'Away, indeed' is a hymn addressed to Vṛṣākapi ; for

Clearly he means that *kapi* in the name '*Vṛṣā-kapi*' stands for *kapila*. Let us see if this meaning suits our hymn. Vṛṣākapi has been called हरितो मृगः 'a tawny-coloured beast' in verse 3. The formation of the compound shows that *kapi* is here a substantive[1] but that constitutes no difficulty for scores of illustrations can be cited from the Ṛgveda of adjectives meaning a particular colour (like हरि, बभ्रु, श्याव etc.) being used as substantives possessing that colour[2]. Though the author of the Bṛhad-devatā takes the first member *Vṛṣan* to be the substantive and the second member *kapi* to be the adjective we can have little hesitation in explaining the compound just the other way. The word *kapi* has been used as a substantive in verse 5. Now *Vṛṣan* comes from root वृष् 'to saturate' and the word means as a substantive 'a potent person or animal', 'a breeder', 'a bull' and as an adjective, 'saturating (with rain)', 'impregnating', 'potent' 'strong'. We may give to the compound *Vṛṣākapi* the meaning of 'the *potent* tawny-coloured animal' or 'the *strong* tawny-coloured animal.' I prefer the former meaning and my reasons will be evident later on.

that brown (*kapila*) bull (*vṛṣan*) is Indra and Prajāpati : 'Indra is superior to all' " is defective. The meaning that the words of Śaunaka can convey is, " 'Away, indeed' is a hymn about Vṛṣākapi ; (beside) that brown bull [*or* that brown bull and] Indra and Prajāpati are the deities (=joint-deities) of the hymn. Indra is highest of all." 'विश्वस्मादिन्द्र उत्तरः' in Śaunaka's verse is not for referring to the hymn, because the opening words 'वि हि' has already served that purpose. It is for showing the relative importance of the three deities mentioned and Saunaka does that in the words of the hymn itself. Indra is thus made out to be the supreme deity of the hymn.

[1] See Macdonell's Vedic Grammar (Grundriss)§ 282 (like *candrá-mās*).

[2] In English too expressions like 'he is riding on a *chestnut*', meaning 'he is riding on a *chestnut-coloured horse*' are not rare.

But we have not yet learnt what particular animal is meant by the name. The language of the Bṛhad-devatā (,'कपिलो वृषा' quoted above) perhaps suggests that the animal meant is, according to Śaunaka, the bull. This is possible, for a wild bull (or a bison?) may be 'a dread beast' (or 'a voracious beast' as Nirukta XIII, 3 explains the word पुल्वघः[1]) and may be chased by a hunter and his dog. But we cannot be sure that no other animal could have been meant. I shall show below that the boar is probably the animal referred to.

The hymn makes it clear that this Vṛṣākapi is related to Indra and Indrāṇī. They are divine beings and Vṛṣākapi too may be a divine being. The Ṛgveda is very fond of figurative expressions and often likens gods to animals. What divine being could possibly be meant by this '*Vṛṣākapi*'? Unaided by external evidence we cannot decide the question. That aid is given by the Nighaṇṭu and the Nirukta. The Nighaṇṭu enumeration of deities in chapter 5 on the whole follows the classification of deities according to the three regions, terrestrial, the atmospheric and the celestial. The name वृषाकपिः occurs in the Nighaṇṭu (*v.* 6) among the 'gods of the celestial region', after विष्णुः, विश्वानरः, वरुणः, केशी and केशिनः and Vṛṣākapi therefore may be a solar deity according to the compiler or compilers of the Nighaṇṭu. Yāska (Nir. XII-28) explicitly calls him Āditya (=Sun). The Bṛhad-devatā follows the Nighaṇṭu and the Nirukta. Śaunaka's words are वृषैष कपिलो भूत्वा यन्नाकमधिरोहति । वृषाकपिरसौ तेन 'विश्वस्मादिन्द्र उत्तरः' । रश्मिभिः कम्पयन्नेति वृषा वर्षिष्ठ एव सः । सायाह्नकाले भूतानि स्वापयन्नस्तमेति यत् । वृषाकपिरितो वा स्यादिति मन्त्रेषु दृश्यते । 'त्रिषु

[1] But this explanation has nothing to commend it, not even perhaps the name of Yāska. पुलु + √घस् would form पुलुघाः and not पुल्वघः. It is highly doubtful if Yāska himself wrote the परिशिष्ट chapters.

धन्वेति हीन्द्रेण प्रयुक्तो वारिषाकपे ॥ (Macdonell's edition, H.O.S., Vol. 5, II 67-69, p. 67). The Gopatha Brāhmaṇa (II. 6. 12) improving on[1] the words (अथ यद्रश्मिभिरभिप्रकम्पयन्नेति तद् वृषाकपिर्भवति वृषाकम्पनः XII. 27) of Yāska says 'आदित्यो वै वृषाकपिस्तद्यत्कम्पयमानेा रेतो वर्षति तस्माद्वृषाकपिस्तद्वृषाकपेर्वृषाकपित्वम्."
The Mahābhārata (Śāntiparva—Mokṣadharma, Ch. 342, vv. 86-87) has the Nighaṇṭu in mind when it says वृषो हि भगवान् धर्मः ख्यातो लोकेषु भारत। निघण्टुकपदाख्याने विद्धि मां वृषमुत्तमम् ॥ कपिर्वराहः श्रेष्ठश्च धर्मश्च वृष उच्यते। तस्माद्वृषाकपिं प्राह कश्यपो मां प्रजापतिः ॥
It is possible that the author of these verses is acquainted with Yāska but he has altered Yāska's explanation 'Vṛṣākapi = the Sun' into 'V. = the abstract deity Dharma or Piety.' The reason for this alteration is quite evident. Setting aside the didactic statement in the Mahābhārata we learn from the other early native works on Vedic gods that Vṛṣākapi is a solar deity.

But does the Ṛgveda give any warrant for this interpretation? I think it does. Let us study the hymn under discussion a bit closely. We find here several attributes of the sun. First of all there are the explicit statements about the setting and the rising of Vṛṣākapi in verses 20 and 21 (अस्तमेहि, पुनरेहि, अस्तमेषि)[2] and the implicit reference to his setting along with Indra in verse 22.

[1] Though I say 'improving on', I am personally not certain which work was later, the Nirukta or the Gopatha Brāhmaṇa. Dr. D. Gaastra has shown (Introduction to his edition of the Gopatha Brāhmaṇa, p. 14) that यस्यै देवतायै हविर्गृहीतं स्यात् तां मनसा ध्यायेद् वषट्करिष्यन् is not a quotation from the Gopatha Brāhmaṇa as Bloomfield and Keith believe. But Guno (Bhandarkar Commemoration Volume, pp. 45, 46) found two other passages in the Nirukta which might have come from the Gopatha Brāhmaṇa. Gaastra has also shown that the Vaitāna Sutra is based on the Gopatha Brāhmaṇa and not *vice versa* (as Weber and Bloomfield assumed).

[2] अस्तं may mean here, as often elsewhere, 'house', but the cumulative evidence is in favour of the sense of 'setting'.

Next, there are other expressions which have been used elsewhere only about solar deities. Vṛṣākapi is brought in immediate connexion with धन्वं (=waste lands), कृन्तत्रं (=कृन्तत्राणि=high regions?) and योजंना (=leagues=plains?) in verse 20 and it is certain that the verse means he has to traverse these. This at once brings to our mind passages like R.V. I. 35. 8 a, b "अष्टौ व्यंख्यत् कुकुभंः पृथिव्यास्त्री धन्व योजंना" said about Savitṛ = Sun and we can hardly doubt that Vṛṣākapi too is the sun. Then again, Vṛṣākapi has been called स्वप्ननंशंनः when going down, in verse 21. Yāska (Nir. XII. 28) gives the word *svapnanamsana* the meaning of 'remover of sleep' and Geldner (Vedische Studien II, 28 and Ṛgveda in Auswahl I—Glossar—p. 209) 'disturber of sleep'. This is on the assumption that *vnas* means here 'to disappear', as always in classical Sanskrit, and its causative form *vnams* 'to drive away'. But the root has in the Ṛgveda a second meaning, *viz.*, 'to attain'; *c.f.* Grassmann, Wörterbuch, 718, '2 naç' and Macdonell's Vedic Grammar for students, p. 395, '2 naś'. It is possible therefore that *svapnanamsana* here means 'bringer of sleep'. The sun certainly lays down people to rest when he goes down[1]. If Yāska's meaning is preferred, even then the Sun can be understood, for he rouses people from sleep when he rises himself. This word alone should conclusively prove that Vṛṣākapi is the sun. And last of all, Vṛṣākapi has been called पुरुवशो मृगः 'dread beast' in verse 22 and I have already noted the parallel expression मृगो न भीमः ('like a dread beast') of I. 154.2 about Viṣṇu, a solar deity.

The combination *vṛṣā-kapi* is by no means an impossible one as a name for the Sun. The Sun certainly looks yellow or tawny and we have in the Ṛgveda

[1]Compare आ कृष्णेन रजंसा वर्तमानो निवेशयंन्नमृतं मर्त्यं च। हिरण्ययेन सविता रथेना देवो याति भुवनानि पश्यन् I. 35.2 etc.

expressions like हरये सूर्याय (X. 96.11) and शाक्मना शाको अरुणः सुपर्ण आ यो महः शूरः सनादनीळः । यच्चिकेत सत्यमित्तन्न मोघं वसु स्पार्हमुत जेतोत दाता ॥ (X. 55.6 where the sun is meant according to Grassmann, Griffith and others). And वृषा 'strong' (or saturator) is a frequent term for Ṛgvedic deities ; compare उरुगायाय वृष्णे in I. 154.3 said about Viṣṇu, a solar deity and पूषा वृषा in X.26.3 about another solar deity. The two epithets have also been combined. Agni has been called a 'brown or tawny *vṛṣan*' in VI.48.6 and VII.10·1. The 'brown bull or breeder' in V.12.6 " यस्ते अग्ने नमसा यज्ञमीट्ट ऋतं स पात्यरुषस्य वृष्णः" may be Agni or may be some deity distinct from itself (the Sun ?). In IX.2.6 " अचिक्रदद्वृषा हरिर्महान्मित्रो न दर्शतः । सं सूर्येण रोचते" ॥ " the Soma has been called a 'tawny *vṛṣan*' and beautiful like Mitra (=Sun) and shining with Sūrya (=Sun). This suggests that Mitra is also a 'tawny *vṛṣan*' and we actually find the Sun called a bull and a ruddy bird in V.47.3 "उक्षा समुद्रो अरुषः सुपर्णः पूर्वस्य योनिं पितुरा विवेश । मध्ये दिवो निहितः पृश्निरश्मा वि चक्रमे रजसस्पात्यन्तौ ॥ " In VII.88.1, " प्रशुन्ध्युवं वरुणाय प्रेष्ठां मतिं वसिष्ठ मीळ्हुषे भरस्व । य ईमर्वाञ्चं करते यजत्रं सहस्रामघं वृषणं बृहन्तम् ॥", the 'lofty *vṛṣan*' is certainly the Sun and in the thirteenth book of the Atharva Veda the Sun appears simply as रोहित = the Red One. Instances may be multiplied. '*vṛṣan*' in *vṛṣakapi* may mean 'strong' or 'potent' and not 'bull'. The saturating power of the Sun is very frequently referred to in the Ṛgveda. May we not now unhesitatingly reject 'Mannaffe' for *vṛṣākapi* and substitute in its place 'strong or potent tawny-coloured animal', understanding thereby the Sun ?

I am now in a position to begin a translation of the hymn. There is not much obscurity about the meanings of the *words*. Consequently the different *translations* do not much differ from one another and mine too will not materially differ from those of my predecessors. There will naturally be a few differences here and

these will be discussed in the notes on the different verses.

"(1) Men have given up the pressing of the Soma and they have not been worshipping Indra, whereas my friend Vṛṣākapi has been exhilarating himself in the wealth (*i. e.* offerings) of the pious (or the rich). Indra is superior to all.

(2) Thou passest by, Indra, without minding the transgression of Vṛṣākapi but thou findest not Soma to drink anywhere else. Indra is superior to all.

(3) What has this tawny beast Vṛṣākapi done to thee, that thou grudgest him now the wealth (or offerings) of the pious (or the rich)? Indra is superior to all.

(4) Thy favourite Vṛṣākapi whom thou protectest, Indra, may the hound bite him, may the boar-hunter seize him in the ear. Indra is superior to all.

(5) This tawny animal has spoiled the dear well-made and brightened things for me and I shall now break his head. I am not going to be indulgent towards a transgressor. Indra is superior to all.

(6) "No Dame hath ampler charms than I, or greater wealth of love's delights.

None with more ardour offers all her beauty to her lord's embrace".[1] Indra is superior to all.

(7) Yes, Madam, easily won, that is what will verily be. My buttocks, Madam, thighs and head seem to shake for very joy. Indra is superior to all.

(8) O thou of lovely arms and lovely fingers, of profuse tresses and broad hips, why afflictest, hero's wife, this our (poor) Vṛṣākapi? Indra is superior to all.

[1] Griffith. I have given his free translation which somehow conveys the sense; for I could myself give only a literal translation and that would have been obscene.

(9) This mischievous creature treats me as one without heroic issues, whereas I am a mother of heroic sons, Indra's wife am I and the Maruts' friend. Indra is superior to all.

(10) From ancient times this lady has been going to the common sacrifice and celebration. She, the rite's ordainer, hero's mother and Indra's wife, has been worshipped (everywhere). Indra is superior to all.

(11) I have heard Indrāṇī as the blessed among all dames for her husband will not age and die even in future time. Indra is superior to all.

(12) I never joyed Indrāṇī, without my friend Vṛṣākapi, whose dear watery oblation goes to the gods. Indra is superior to all.

(13) O bounteous Vṛṣākapāyī, having good sons and daughters-in-law too thy Indra will eat the dear... oblation of bulls. Indra is superior to all.

(14) They cook for me together fifteen bulls (or) twenty and I take their fat and they fill my belly on both the sides. Indra is superior to all.

(15) Let this drink, Indra, please thy heart, which is strong like a sharp-horned bull, bellowing among the herds, and which is pressed for thee by the person who wants to win thy love. Indra is superior to all.

(16), (17) (See commentary of Sāyana quoted below).[1]

[1] हे इन्द्र स जनेा नेशे मैथुनं कर्तुं नेष्टे न शक्नोति यस्य जनस्य कपृत् शेपः प्रजननं सक्थ्या सक्थिनी अन्तरा रम्बते लम्बते सेत् स एव स्त्रीजने ईशे मैथुनं कर्तुं शक्नोति यस्य जनस्य निषेदुषः शयानस्य रोमशमुपस्थं विजृम्भते विवृतं भवति यस्य च पतिरिन्द्रो विश्वस्मादुत्तरः ॥१६॥ स जनेा नेशे मैथुनं कर्तुं नेष्टे यस्य निषेदुषः शयानस्य रोमशमुपस्थं विजृम्भते विवृतं भवति सेत् स एव जनः ईशे ईष्टे मैथुनं कर्तुं शक्नोति यस्य नरस्य कपृत् प्रजननं सक्थ्या सक्थिनी अन्तरा रम्बते लम्बते। सिद्धमन्यत्। पूर्वोक्तव्यतिरेकोऽत्र द्रष्टव्यः। पूर्वस्यामृचि यियप्सुरिन्द्राणीन्द्रं वदति अत्रायियप्सुरिन्द्र इन्द्राणीं वदतीत्यविरोधः ॥१७॥ ईशे = ईष्टे really means 'is strong or potent.'

(18) May, Indra, Vṛṣākapi obtain a victim of wild beasts (?), the knife, the oven, the new pan and also a cart with fuels filled. Indra is superior to all.

(19) I come viewing all the quarters discriminating the Dāsa and the Ārya and I drink the Soma pressed only by the guileless votary and I look (with favour) on the wise. Indra is superior to all.

(20) The deserts, and the steep regions and how many are the leagues (thou hast to pass)! Through them come down Vṛṣākapi to thy neither homes. Indra is superior to all.

(21) Come again Vṛṣākapi, blessed enjoyments we (too) shall arrange (for thee or for ourselves), thou who bringing sleep goest (down) again to thine home by thine (olden) path. Indra is superior to all.

(22) When you, Vṛṣākapi and Indra, who were on the upper heavens, went to your home, where was then the dread beast, where went that charmer (?) of people? Indra is superior to all.

(23) Parśu, the human wife, brought forth together twenty children. It is good that happened to her whose womb had swelled and caused her pain. Indra is superior to all.'

What story does the hymn tell us? According to Professor Macdonell[1], "This hymn describes a dispute between Indra and his wife Indrāṇī about the monkey Vṛṣākapi, who is the favourite of the former and has damaged the property of the latter. Vṛṣākapi is soundly threshed and escapes, but afterwards returns when a reconciliation takes place." Professor Geldner[2] says that it is "a dramatic scene in genuine popular style. Vṛṣākapi, an ape and a bastard of Indra, had on account of a threshing left the house and he has now alone and without Indra,

[1] Vedic Mythology, p. 64.
[2] Der Ṛgveda in Auswahl II (Kommenter) p. 184.

called on people who are celebrating his worship and have thereon almost forgotten the God (Indra) himself. During their vain search for Soma, Indra and Indrāṇī meet their naughty son and his consort at a banquet." Grassmann writes,[1] "Dialogue between Indra and Indrāṇī in the presence of Vṛṣākapi and his wife Vṛṣākapāyī. Vṛṣākapi, literally 'the strong ape,' 'the male ape', who has been directly called kapi *i. e.* ape in verse 5, appears here as a being intermediate between a demigod and a demon. While he is a friend and comrade of Indra and sacrifices to him with zeal, he behaves himself wantonly with his wife Indrāṇī and torments people. The refrain at the end of each verse; 'Highest of all is Indra,' obviously did not belong to the original hymn and since it breaks the connection everywhere, it has been omitted in the following translation. The hymn is twice interrupted by obscene passages (vv. 6, 7, 16, 17) that break the connection and also seem to have formerly formed natural parts of hymns in which husband and wife speak together. Verses 6 and 7 appear to have been taken from an obscene hymn and most likely verses 16 and 17 too. Vṛṣākapi threatened by Indrāṇī has been defended by Indra, especially on account of a sacrifice which he and his family offer to Indra, whereon Indrāṇī (v. 15) praises the brew she has prepared and derides the offering of Vṛṣākapi (v. 18). This Vṛṣākapi seems to have wished to fly away to impassable regions before the anger of Indrāṇī. Indra gives him his own and his wife's protection and asks him to return to the house (vv. 20-21)." Tilak in his Orion (Chapter VII) tries to prove that the hymn has an astronomical meaning. According to him, Vṛṣākapi is the Sun who has the vernal equinox in the Orion. After the autumnal equinox, the Sun passes to the southern hemisphere and Tilak thinks that sacrifices were then

[1] Ṛgvda, übersetzt, II, p. 484.

stopped. According to him the hymn records Indrāṇī's chagrin at this stoppage of sacrifices for her lord; and she is wroth with the *mṛga* (Orion) whose acronycal rising was "a signal to stop such ceremonies, and oblations could properly be said to have been spoilt by the appearance of this constellation at the beginning of night" [1]. Indrāṇī wishes to cut off (=actually cuts off, according to Tilak) this *mṛga's* head and the cut off head of the 'antelope' is the constellation *Canis Major*. Indrāṇi is reconciled with Vṛṣākapi (=the Sun) when he comes back *i. e.* returns from the southern hemisphere (at the vernal equinox), whereon sacrifices can go on again.

In interpreting obscure passages of an old text like the Ṛgveda the imagination has to be exercised a good deal. But this faculty should be used with considerable restraint. I cannot help feeling that my predecessors used their imaginations too freely. The ultimate determining factor is the text itself. I have used my imagination in the understanding of the hymn but have confined it within the narrow limits of actual text and have throughout sought (and found) parallels for the meanings that the words of the hymn seemed to warrant. I now give below my own interpretation but before doing that I must offer some remarks about the views quoted above. The European interpreters have been all misled by their supposition that *kapi* in *Vṛṣākapi* means 'an ape.' But I have shown already that *kapi* should mean 'a tawny-coloured animal' and *Vṛṣākapi* stands for the Sun. This natural supposition would have saved Geldner and Grassmann from a host of wild guesses. Geldner[2] thinks that the statement of Ṣaḍguruśiṣya "वृषाकपिर्नामेन्द्रस्य पुत्रः शचीसपत्न्यां जातः" means that *Vṛṣākapi* is a *bastard* of Indra. This betrays a lamentable ignorance of Oriental conditions.

[1]Orion (reprinted by Ashtekar, p. 179).
[2]Vedische Studien, II, 23.

Monogamy was not a rigid rule in the time of Ṣaḍguru-śiṣya or Sāyaṇa or the seers of the Vedic hymns themselves. Indrāṇī's co-wife, the mother of Vṛṣākapi would be as good a married wife of Indra as Indrāṇī herself and consequently Vṛṣākapi would be as legitimate a son of Indra as Indrāṇī's sons would be. Besides showing an unbridled imagination Grassmann makes a number of assumptions about the original text of the hymn which have no warrant save his own inability to understand the connections. Against Tilak, I have to say that *mṛga* does not mean in the Ṛgveda an 'antelope' but 'any wild animal' (an animal of the chase) and he has himself admitted that no trace of the constellation *Canis Major* (Tilak's Śvan in Sanskrit) is found in Sanskrit literature. Hence all those suppositions about the cut-off head of the antelope with a dog-star behind it at the acronycal rising of the Orion when sacrifices have to be stopped at once fall to the ground. No scientific mind will consider seriously an interpretation according to which Vṛṣākapi at one place means the Sun in the Orion, and at another place in the same hymn the constellation Orion rising in the eastern horizon when the Sun sets (being now at a distance of 180° from the constellation). I do not say more, because to show the untenability of the various assumptions of Tilak would require double the space he has himself devoted to the subject. It is a matter of pity for the cause of science that the greatness of Lokamānya Tilak's character, both personal and political, and his real fame for vast erudition create an undue prejudice in our country in favour of his historical conclusions.

Now for my own interpretation. The hymn most clearly refers to an orthodox opposition against the worship of Vṛṣākapi (= Viṣṇu = the Sun god) to the exclusion of the old national god Indra. This opposition

is expressed dramatically through the mouth of Indrāṇī, Indra's wife, who is the person that is most likely to be affected at her husband's loss of worship. She is naturally indignant with Vṛṣākapi for whose sake her lord has been deprived of his wonted oblations (vv. 1 and 2). She tries to rouse the anger of her all-powerful lord against this insolent beast (vv. 1, 2, 5, 9) but all her efforts fail and the old hero expresses his love for and kinship with Vṛṣākapi whose celebration cannot move him to jealousy (vv. 3, 8, 12). Indrāṇī fails and the worship of Vṛṣākapi receives the weighty support of Indra himself (vv. 19-21). The 'seer' of the hymn, who is obviously an exclusive worshipper of this deity Vṛṣākapi (=Viṣṇu=the Sun god), cleverly disarms orthodox opposition by making Indra himself sanction this worship and by the diplomatic[1] refrain at the end of each verse, "विश्वस्मादिन्द्र उत्तरः" (Indra is the highest of all). This interpretation is based on the actual text (in the understanding of which the imagination has been used with considerable restraint) and it leaves no portion of the hymn out of account. The refrain, verses 6 and 7 and 16 and 17 and 23 (the concluding one which none has ere this been able to satisfactorily connect with the previous verses) have all been found to be connected with the rest of the hymn. I have also found Ṛgvedic parallels for all the new meanings I have proposed. Let me now give reasons for the few innovations I have made in the *translation* and for the new *interpretation* I have just proposed and let me further explain my position. This will be best done by taking up each verse and discussing its meaning. I may, however, mention here the legend given in the Brahma Purāṇa (ch. 129) of Abjaka Vṛṣākapi, a man having the nature of Śiva and Viṣṇu, who was produced from the water by

[1] The person who verbally acknowledges the supremacy of Indra cannot be branded as a 'heretic'.

15

Siva, the Godāvarī and Viṣṇu at the prayer of Indra and Śacī. It is possible that the Purāṇa understands *kapi* to mean a *monkey* but that is quite natural. I therefore do not feel disposed to accept the suggestion of Mr. Pargiter (J. R. A. S., 1911, p. 808—9) about the Dravidian origin of the Vṛṣākapi cult or to think that the Purāṇic story is not based on our hymn.

Verse 1—This verse is put in the mouth of Indra by Ṣaḍguruśiṣya, Sāyaṇa and Geldner but of Indrāṇī by Mādhavabhaṭṭa (quoted by Sāyaṇa on X. 86.1), Durgācārya (on Nir. XIII.4) and Ludwig. I take it to be spoken by Indrāṇī for it contains a note of complaint. Indra would not complain against Vṛṣākapi who is his favourite (cf. v. 12) अर्यः is taken by Yāska (?)[1], Sāyaṇa and Geldner in the Second Volume of the Vedische Studien as nominative singular of अर्य (meaning 'lord', an adjective of वृषाकपिः). But Geldner in the Third Volume of his Vedische Studien (III. 86) and in the Kommentar (p. 184) corrected himself by taking it as genitive singular of अरि (= आर्य = Aryan). Oldenberg (Ṛgveda, text kritische and exegetische Noten, II, 290) supports this correction. अर्यः should be therefore connected with पुष्टेषु. Indrāṇī complains that when Vṛṣākapi (who is only her 'friend', or relation) is revelling at the feasts Aryans are offering, her husband gets neither his wonted libation of Soma nor the worship ($\sqrt{man}$ = to worship) Aryans had been offering him so long. Indrāṇī cannot brook this insult of her husband (and of herself) when she sees Vṛṣākapi preferred to her lord. As is usual with women in such circumstances, she becomes angry with Vṛṣākapi.

Verse 2.—This verse is ascribed by all to Indrāṇī and there can be no doubt on the point. Indrāṇī is

[1]Nir. XIII. 4. It is highly doubtful if Yāska is the auther of the supplementary chapters (XIII and XIV).

wroth with Vṛṣākapi for he eats and drinks the offerings (principally the Soma) that were her husband's due and she points out to Indra the transgression of this wretch. She wonders why her husband feels no anger against this transgressor; Indra should not condone the offence for he is getting nothing himself ("thou dost not get Soma to drink in any other place").

Verse 3.—Ṣaḍguruśiṣya and Sāyaṇa ascribe this verse to Indrāṇī but Geldner, Griffith, Ludwig and Oldenberg are more justified in putting it in Indra's mouth. Indrāṇī has tried in the previous verse to rouse the anger of Indra against Vṛṣākapi but Indra asks in wonder what makes her so much wroth with Vṛṣākapi that she grudges him the rich offerings of the Aryans 'हरितो मृगः = कपिः = 'yellow or tawny-coloured animal'. अर्यः here has the same formation and syntactical connection as in v. 1.

Verse 4.—Attributed by all to Indrāṇī. Indra's astonished question makes Indrāṇī lose her temper. She had expected that Indra would be estranged from Vṛṣākapi the moment she brought to his notice the latter's offence. But she finds to her horror that Indra is speaking sympathetically about Vṛṣākapi. She now starts the various feminine guiles for inducing a husband's obedience. The first weapon that she uses is a show of violent passion. She curses the wretched animal (Vṛṣākapi) whom Indra seeks to defend. Griffith takes वराहयु to be an adjective to श्वा and translates *c* and *d* as one sentence: "Soon may the hound who hunts the boar seize him and bite him in the ear." This construction is possible or perhaps probable but not altogether certain. In taking *d* separately we have to supply a new verb, for जम्भिषद् will not do here. On the other hand कर्णे is better construed with *c*. Consequently *d* should be connected with *c*. But if we supply in *d* some verb meaning 'may shoot' or 'may pierce', "let the boar-hunter shoot at or pierce his

ear" will by itself make quite good sense. Griffith's construction though simpler has the defect of making अपि superfluous. However, I leave the question undecided. But I ask my readers to remember the word वराहयु for I shall have to refer to it again.

Verse 5.—Again Indrāṇī's words according to all authorities. Indrāṇī continues in the same vein. But she first gives the ground for her anger. She has already said how Vṛṣākapi has been snatching away the portion of Indra. This altogether failed to make any impression on Indra for he asked in wonder why he grudged the 'beast' his sacrificial feast. Indrāṇī therefore changes her charge and now gives out that Vṛṣākapi had harmed *her* too. What is the harm she had suffered at his hands? Grassmann and Griffith suppose that Indrāṇī accuses Vṛṣākapi of having wantonly assaulted her. But where is the text to warrant such a view? The words are simply "प्रिया तष्टानि मे कपिर्व्यक्ता व्यदूदुषत्" here. कपिः is a short form for वृषाकपिः and has the same meaning ('tawny'—tawny-coloured animal) as हरितो मृगः in v. 3. What things of Indrāṇī does this 'tawny-coloured animal' spoil? Geldner[1] supposes that प्रिया तष्टानि = the delightful limbs of Indrāṇī in which lies her womanly attraction but about which Vṛṣākapi speaks ill (व्यदूदुषत्). But the word तष्टानि does not warrant this interpretation. It is derived from √तक्ष् 'to artifice'; तष्टानि would therefore mean 'well-made'. व्यक्ता is from √अञ्ज् 'to besmear;' व्यक्ता (= व्यक्तानि) would literally mean 'well-besmeared'. I therefore see no reason for rejecting the interpretation of Sāyaṇa for तष्टानि ('यजमानैः कल्पितानि हवींषि 'offerings prepared by the worshippers') and व्यक्ता ('आज्यैर्विशेषेण अक्तानि' 'well-besmeared with *ghee*). मे may be in the sixth case ('of me') or, as Sāyaṇa takes it, in the fourth—dative of interest ('for me').

[1] Kommentar, p. 185.

Consequently I understand 'प्रिया तष्टानि मे कपिर्व्यक्ता व्यदूदुषत्' to mean that Indrāṇī accuses Vṛṣākapi of having spoiled the offerings of sacrificial cakes &c., she had been expecting, by eating of them and thereby turning the things into impure offals. This is a personal insult and as Indra seems to preserve a stolid appearance, Indrāṇī proposes to take the law into her own hands and punish the transgressor herself.

Verse 6.—Indrāṇī speaks again. She attempted to rouse the anger of Indra against Vṛṣākapi by mentioning in verses 1 and 2 how Indra was being injured by Vṛṣākapi. Verse 3 shows the callousness of Indra. In verse 5, Indrāṇī said that she too was harmed by this 'tawny beast' and in the same way. To make Indra feel for her she now recounts her personal charms expecting thereby to seduce him into compliance. Her threat in v. 5 *cd* was an idle one.

Verse 7.—This verse is ascribed by Ṣaḍguruśiṣya, Sāyaṇa, Geldner and Oldenberg to Vṛṣākapi and by Ludwig and Griffith to Indrāṇī. There is nothing in the previous verse to show that it was addressed to Vṛṣākapi. Why should then Vṛṣākapi thrust himself here? इष्यति cannot be satisfactorily explained if Vṛṣākapi is the speaker here. The root इष् means 'to be excited.' Vṛṣākapi's head may *tremble* for fear but cannot surely be *excited* with joy or (anger) and this 'trembling for fear' can be understood only after Indrāṇī's threats in verses 4 and 5 and not after the mention of her personal charms in verse 6. Besides, the address सुलाभिके ('O thou, easy of access') for Indrāṇī is altogether inappropriate in Vṛṣākapi's mouth. She is not his wife but Indra's. Nor can the verse be ascribed to Indrāṇī for who can then be 'the mother easy of access'? I therefore propose to take this verse as coming from Indra as the following one is according to all opinions. Verse 6 was apparently

addressed to him and we may well expect his reply now. It is the vocative अम्ब ('mother') that has misled these interpreters for Indrāṇī is Indra's wife and not mother. Tilak who ascribes this verse to Indra says, "I prefer taking *ambā* as an affectionate and respectful mode of address, as in modern Sanskrit, and the verse presents no difficulty." But apparently अम्ब means (or may mean) 'O mother of your child (Vṛṣākapi)'. In many countries, fathers often address their wives as 'mother'—meaning of course 'mother of our children'. The word अम्ब may have been similarly used here. Indrāṇī mentions her personal charms in v. 6. Indra admits her superiority in beauty in v. 7 *a* and *b*: though Indrāṇī surrenders her charms for enjoyment, almost unasked, these are of no mean order—she is really, as she claims to be, the first in beauty. Indrāṇī's personal charms are also referred to elsewhere; compare Maitrāyanī Samhitā III, 8, 4 and Taittirīya Brāhmaṇa II, 4-2-7. In v. 7 *c* and *d*, Indra admits with great courtesy [1] that her charms have an appeal for him.

Verse 8.—Indra's words according to all authorities. Indra repeats in lines *a* and *b* the excellence of Indrāṇī's personal charms. But in *c* and *d* he asks her again what makes her angry with Vṛṣākapi. There seems to be some significance in the address शूरपत्नि ('O hero's wife'): it is probably meant that a hero's wife should not chastise a poor creature like Vṛṣākapi.

Verse 9.—Indrāṇī replies. अवीराम् is paraphrased in the Nirukta (VI. 31) by अबलाम्. But the accent is not of a नञ्तत्पुरुष but of a बहुव्रीहि [2]. Consequently the meaning is 'not having heroes (or a hero)'. Now वीर in

[1] I say 'with courtesy', because the इ (वि is to be connected with इष्यति) shows that his body is not actually excited with joy.

[2] Pāṇini VI. 2.2 (with Vārtika on it) and VI. 2.172. Macdonell's Vedic Grammar (Grundriss) § 890 Bc. and 91 A. 2-b.

the Ṛgveda generally means [1] 'a heroic son' or simply 'a son'. अवीराम् in line *a* is matched by वीरिणी in line *c* which certainly means 'having a hero or heroes'. Griffith translates '"अहम् अस्मि वीरिणी' by "Heroes for my sons have I". Why does he render then अवीराम् by "one bereft of hero's love"? Geldner renders *vīrā* in both अवीराम् and वीरिणी by 'son'. Childless women are generally held in much contempt. Indrāṇī says that she is being treated as such a one by Vṛṣākapi. But she emphatically declares that she is वीरिणी 'with children' for she is Indra's wife who can never be childless. Vṛṣākapi is certainly not her own son. Then what is her issue? 'I am a friend of the Maruts' probably means that these Maruts are her sons. I translate *sakhā* by 'friend' in verses 1 and 9; but it is possible that in both the places the word has the connotation of *kinship*. A lady blessed with heroic children (the Maruts?) should not be deprived of her share in the festive offering—consequently Vṛṣākapi has no justification in snatching away her portion. It seems now that Ṣaḍguruśiṣya is right in conceiving Vṛṣākapi as the step son of Indrāṇī. Indian folklore abounds in stories of a step-mother afflicting her step-son and we find here Indrāṇī trying to alienate her husband from her 'step-son' Vṛṣākapi.

Verse 10—Ṣaḍguruśiṣya and Sāyaṇa ascribe this verse to Indrāṇī. Similarly Ludwig and Griffith. Geldner in the Vedische Studien [2] put it in the mouth of Vṛṣākapi but later [3] corrected himself by making Indrāṇī or Indra the speaker. Oldenberg too understands it as coming from the mouth of either Indrāṇī or Indra. I do not know for certain to which of the two the verse could be ascribed with better justice; it may be equally

[1] See Grassmann, Wörterbuch, 1316.
[2] II, 26.
[3] Kommentar, 185.

understood as Indrāṇī's speech or as Indra's utterance. However I give preference to Indrāṇī hypothetically. But the meaning remains unaltered in either case. . Barren women are considered a curse and they are likely to be excluded from festive meetings. But Indrāṇī, verse 10 informs us, is both the 'mother of heroes' (वीरिणी) and has accompanied her husband to sacrifices. [In actual ritual Indrāṇī had a share in the sacrifice.]

Verse 11—This verse is attributed to Vṛṣākapi by Durgācārya (on Nir. XI. 38). Geldner makes Vṛṣākapāyī (wife of Vṛṣākapi) the speaker but his reasons are not apparent to me. Ṣaḍguruśiṣya, Sāyaṇa[1], Ludwig, Griffith and Oldenberg ascribe it to Indra. I think they are correct; for Indrāṇī addressed Indra and we would expect him to reply. The following verse which is certainly Indra's does not contain any indication of a fresh speech. Leaving out the uncertain verse 10, we may hold that Indra replies to Indrāṇī in vv. 11—14. In v. 11, Indra tries to soothe Indrāṇī. He says that she is the luckiest of women. Women in India (and probably everywhere else) consider the longivity and love of their husbands and the existence and well-being of their sons as the highest fortune. Indrāṇī has this fortune. How then can she be excluded from sacrifices? The word *subhāgā* probably means here both beautiful and fortunate.

Verse 12—Durgācārya ascribes it to Vṛṣākapi[2] perhaps carelessly for he contradicts himself in the very

[1] Sāyaṇa's alternative ascription to Vṛṣākapi is the result of Durgācārya's influence.

[2] "समाना विनियोगः पूर्वया, आर्षं च" on Nir. XI. 39 (M. M. Pandit Sivadatta's edition). The previous verse commented on is the preceding one of our hymn, where Durga said "वृषाकपेरार्षम् ".

next sentence by saying "इन्द्रो ब्रवीति". All else ascribe the verse to Indra. Indra tried to soothe Indrāṇī in the previous verse by making her the luckiest of women. He fully understands that Indrāṇī's real complaint was that Vṛṣākapi was receiving worship in the place of Indra and that the accusation in verses 5 and 9 is a clever lie or at least is secondary (being thrown out to rouse Indra from his callousness). Consequently he now gives his reply only on the point of his own alleged loss of worship[1]. He says that he never enjoys without his friend Vṛṣākapi. Consequently how can he envy him the worship and oblations that he is receiving? अप्यं हविः 'watery oblation' probably refers to the Soma juice. Not only is Vṛṣākapi dear unto Indra, he is the favourite of all the gods. His dear oblation goes to all the gods and that means that all the gods enjoy his worship. How then can Indrāṇī incite envy against this dear friend of Indra? [It should be remembered that Viṣṇu has been called इन्द्रस्य युज्यः सखा 'Indra's fast friend' in R.V. I. 22. 19].

Verse 13—Now comes some difficulty. Ṣaḍguruśiṣya, Sāyaṇa, Ludwig, Geldner and Griffith ascribe the verse to Vṛṣākapi but it seems better to follow Durgācārya[2] and Oldenberg in understanding Indra to be the speaker. Indra is the speaker of verses 12 and 14. What expression is there in v. 13 to show that it comes from a different mouth? The vocative वृषाकपायि presents great difficulty. Who is this Vṛṣākapāyī? The formation of the word seems to make her the wife of Vṛṣākapi and this is the only meaning which classical usage can attach to

[1]Had Indrāṇī charged Vṛṣākapi with having wantonly assaulted her as Grassmann and Griffith suppose, we would certainly have had Indra's reply on the point, if not actual retribution for that misdeed.

[2]On Nir. XII. 9.

the word. Yāska (XII-8) following this usage ascribes this meaning to the word and he seems to be supported by the Nighaṇṭu (v. 6) enumeration. But it is possible that Vṛṣākapāyī means here Vṛṣākapi's mother (=step-mother, *i.e.* Indrāṇī) and not wife. This is the only meaning that can apparently suit the context. Sāyaṇa knew Yāska's words and the usage of his time. Still he felt constrained by the actual text to reject them in favour of the meaning 'Indrāṇī'. His words are interesting as they show how he seeks not to do violence to the accepted formation of *Vṛṣākakāpī*; he says, "हे वृषाकपायि । कामानां वर्षकत्वाद्भीष्टदेशगमनाच्च इन्द्रोवृषाकपिस्तस्य पत्नि । यद्वा (being more sensible now) वृषाकपेः = मम (because he ascribes the verse to Vṛṣākapi) मातर् इत्यर्थः" The mention of her good sons and daughters-in-law may make one take Vṛṣākapāyī to be none other than Indrāṇī who has emphatically called herself वीरिणी ('mother of heroes) in verse 9. The wealth referred to in the vocative रेवति connects itself naturally with the good fortune mentioned in verse 11. Verse 13 may therefore be taken as Indrā's words addressed to Indrāṇī. Indra continues with his consolation. He first humours Indrāṇī by mentioning her wealth of children. He now says that he will take the offering of bulls. This probably means that though Vṛṣākapi gets the Soma oblation, Indra is not going unfed, for bulls are being offered to him. It is possible (or rather certain) that the Soma formed the chief offering and oblation of bulls etc. may possibly have been given to the secondary deities. Indra was the chief god of the Aryans for ages and the Soma was his especial food. But the present hymn shows him brought down to a lower place and Vṛṣākapi (=the sun=Viṣṇu) elevated to his seat. Consequently our poet makes Indra approve the offering of Soma for Vṛṣākapi in verse 12 and the oblation of bulls for himself in verse 13. The word

कारिस्करम् is obscure to me and I have therefore left it untranslated in the rendering given above. Yāska gives it the meaning 'giving great joy'. Sāyaṇa necessarily follows him. Of European interpreters, Geldner[1] gives with a little hesitation 'what is of worth', Grassmann 'efficacious' and Ludwig and Griffith 'that which effecteth much'. The adjective प्रियं shows that Indra is thoroughly satisfied with the हविः that he is now getting and he has therefore no cause to be jealous of Vṛṣākapāyī. ते can be connected with उक्षणः = 'thy bulls', but I prefer to connect it with the word that immediately follows it, *viz.*, इन्द्रः; त इन्द्रः = 'thy Indra' = 'Indra in whom thou art particularly interested'. That the bulls are not the offerings of Vṛṣākapāyī (= Indrāṇī) but of the human worshippers is evidenced by the plural number in the verb पचन्ति of the following verse.

Note.—If वृषाकपायि cannot mean 'Vṛṣākapi's mother' but must needs mean, on the analogy of अग्नाय्यी (इन्द्राणी, वरुणानी etc.), 'Vṛṣākapi's wife', considerable alteration will have to be made in the interpretation of this verse. I can suggest an alteration which would both suit the context and fit in with my interpretations of the remaining verses (with, of course, slight modifications here and there). See below under note on verse 19 for this meaning which I *prefer* though I have relegated it to a note.

Verse 14.—The verse is ascribed by all to Indra and no doubt is possible on the point. Indra makes here a complimentary reference to the bulls that worshippers cook for him. The number of these bulls is according to Sāyaṇa 15+20=35. But I prefer to take it as '15 *or* 20'; if च can be supplied, surely वा can be.

Verse 15.—It is put in the mouth of Vṛṣākapāyī by Geldner and to herself or her husband Vṛṣākapi

[1] Glossar, p. 44

by Oldenberg but their reasons are not apparent to me. I therefore follow Ṣaḍguruśiṣya, Syāaṇa, Ludwig and Griffith in attributing the verse to Indrāṇī. Indrāṇī now tries to win over Indra to her own view by rousing in him a temptation for the Soma draught. Indra has said in v. 12 that he is satisfied that the offering of Soma goes to Vṛṣākapi, which all the gods enjoy, and in vv. 13[1] and 14 that he is himself contented with only the offering of bulls. Indrāṇī now (in v. 15) praises the draught of Soma that his भावयुः prepares for him. The भावयुः ('seeker of his *bhāva*=love') may be Indrāṇī herself, in which case the Soma offering is made by her. But this is neither certain nor necessary, for the word may easily mean any devoted worshipper of Indra (*i.e.* an orthodox Aryan who had not given up pressing of Soma for Indra). Indra has expressed satisfaction at the bulls he is now getting as his portion. Indrāṇī therefore calls the Soma drink which he is now willingly going without as "like a sharp-horned bull bellowing among the herds." She expects thus to rouse his old fondness for this drink and then to make him jealous of Vṛṣākapi, the fellow who has usurped his place at the sacrifice.

Verse 16.—All ascribe this verse to Indrāṇī and I have no hesitation in following them. Wine and woman are the two great seducers of man. Indrāṇī tried the seduction of the former in the previous verse. Of the latter she has made an attempt already (v. 6) but she makes here a last frantic effort. She here derides the person who refrains from intercourse with woman. Her hope is that Indra will no longer be able to contain himself but will give himself up to her charms; and she will secure the banishment of Vṛṣākapi from the general

[1]But also see below under note on v. 19.

worship of people[1]. Geldner thinks that स: in the first half refers to Vṛṣākapi and in the second to Indra. But what ground is there for such a difference in treatment? Two different types of men are contrasted here: the type mentioned in the first half is that of the celibate whom Indrānī derides as impotent and in the second comes in the bull-blooded gallant who is the really strong man according to her. Geldner's quotation[2] from the Hitopadeśa[3] is neither here nor there but the reference to R. V. VIII. 1. 34 is quite apposite.

Verse 17.—Geldner ascribes it to Vṛṣākapāyī but there can be no sense in this view. I have already shown that *Kapi* in *Vṛṣākapi* does not mean 'monkey.' There is besides no difference between a monkey and a man (or a god anthropomorphically conceived) that would justify Vṛṣākapi's wife in reversing the statement of Indrāṇī[4]. I therefore feel no hesitation in rejecting Geldner's view. Ṣaḍguruśiṣya makes Indrāṇī the speaker. But why should she think of contradicting herself, of saying here just the opposite of what she has recently said? According to Sāyaṇa's statement in the सूक्तावतरणी

[1] Compare Kekayī's (successful) attempt in the Rāmayaṇa to secure the banishment of Rāma on the strength of her loving services to King Daśaratha rendered in the past. Compare also Iliad XIV, where Hera charms away Zeus from the view of the battle, that her own partisans, the Achaians, may not be thwarted by the great god in their attempts against Hector and the Trojan host.

[2] Kommentar, p. 186.

[3] "ततः तस्य मुष्कद्वयं लम्बमानम्", Hitopadesa, ed. Peterson, p. 50.

[4] Had the hero of the Hitopadesa story been a man, his मुष्कद्वय would not have been लम्बमान only because of his clothes whose use the poor monkey did not know. The apish character lay not in the dangling of the मुष्कद्वय but in the animal's pulling out the wedge

too, Indrāṇī is the speaker of (this) verse but in his comments on the verse he makes Indra the speaker. Indra is the speaker according to Ludwig too. This is perfectly intelligible and I follow it. Indrāṇī set a trap for Indra in the previous verse and he here just refuses to be caught in it. He denies the correctness of her statement. He says that the person who wastes his manhood in sexual intercourse is the really impotent man, and the strong man is he who stores up his energy by continence. Sāyaṇa's remark on the difference with the previous verse deserves quoting again: "पूर्वोक्तव्यतिरेकोऽत्र द्रष्टव्यः। पूर्वस्यामृचि यियप्सुरिन्द्राणी इन्द्रं वदति अत्र अयियप्सुरिन्द्र इन्द्राणीं वदतीत्यविरोधः॥"

Verse 18.—Ṣaḍguruśiṣya, Sāyaṇa, Griffith and Ludwig ascribe it to Indrāṇī. Geldner stands alone in making Vṛṣākapāyī the speaker and he may be safely left alone. No wife of Vṛṣākapi probably takes part in this dialogue.[1] परंस्वन्तम् is a difflcult word and I do not understand its precise meaning. A wild animal may be meant but what particular animal I cannot make out. Indrāṇī's purpose has been foiled by Indra and she has no choice but to make up her quarrel. She now suffers Vṛṣākapi to receive हतं परंस्वन्तम्, असिम्, सूनाम् and all that gear.

Note.—Does Indrāṇī want to suggest with feigned innocence that Vṛṣākapi should receive in the sacrifice animal offerings (which are really of secondary importance), [so that the chief offering—the Soma—might go over to her lord]? परंस्वन्तम् would then correspond to 'the fifteen or twenty bulls' Indra shows himself contented with in verse 14.

Verse 19.—All previous interpreters have put this verse in Indra's mouth and this ascription may be correct. If so, Indra probably means that as he goes about viewing people and discriminating between the Aryan and the

[1]Though of course she may have been addressed in v. 13.

non-Aryan, he cannot accept any and every offering that is given to him but must needs make a selection—पिबामि पाकसुत्वनः : 'I drink of the oblation offered by the artless votary'. Hence what cares he if he is not universally worshipped? But probably Indra is not the speaker here. Indrāṇī has already said (v. 2), नो अह प्रविन्दस्यन्यत्र सोमपीतये 'Nor receivest thou elsewhere Soma to drink.' It is difficult therefore to understand पिबामि पाकसुत्वनः to refer to Indra. The root *su* shows that the Soma drink is meant. If Indra is *nowhere* offered Soma, according to Indrāṇī's statement, how can he have the drink of guileless (पाक) pressers of Soma (सुत्वन्)? I therefore propose to take Vṛṣākapi to be the speaker. The previous verse shows Indrāṇī reconciled to him and he may have made bold to open his lips now. Vṛṣākapi is certainly glad now and can we not expect him to break into a description of his own doings? "I come viewing all the quarters, discriminating the Dāsa and the Ārya" would be more appropriate in the lips of Vṛṣākapi, a solar god; though "discriminating the Dāsa and the Ārya" alone will easily suit Indra. In VIII $\frac{80}{91}$2 it has been said about Indra "एषि...गृहंगृहं विचाकशत्" 'thou comest looking from door to door' and that may be considered as parallel to "अयमेमि विचाकशत्" here. But the passage in the eight *maṇḍala* qualifies विचाकशत् by गृहंगृहम्—Indra looks at every door (for his coveted Soma)—whereas in the passage under discussion, there being no such qualification, 'viewing all the quarters' would be the only natural sense. This latter meaning is more intelligible in the case of a solar deity; *c. f.* 'वि जनांश्छ्यावाः शितिपादो अख्यन्' (I. 35. 5), "वि द्यामेषि...पश्यञ्जन्मानि सूर्य" (I. 50. 7) etc. If we take Vṛṣākapi to be the speaker, the whole verse becomes easily intelligible and connection with the previous and the following verses becomes quite patent. Indrāṇī said in v. 18 that Vṛṣākapi might receive his (usual?) meat offering and he probably brags now of his greatness—as he goes through the firmament viewing all

creatures, he can well understand who is the Aryan (bounteous) offerer and who is the Dāsa (niggard). Indra has been frequently mentioned as preferring the bounteous Aryan over the niggardly non-Aryan (Dāsa or Paṇi). Vṛṣākapi therefore probably lays claim to the same function. He complacently speaks of how he accepts the Soma drink (that was formerly Indra's wont). The connexion with the following verses will be manifest below.

Note.—If the suggestion thrown out in the previous note can be accepted, the following alteration should be made. Indrāṇī suggested in v. 18 with feigned innocence that Vṛṣākapi should content himself with offerings of animals (only). But the clever Vṛṣākapi, supremely conscious of his own importance and Indra's kind indulgence, replies here, "I travel through the whole firmament looking at people and discriminating the Dāsa and Ārya (and I shall therefore claim, as a matter of right, the Soma offering of the pious = Aryan worshipper)". Failing to win Indra over to her view, Indrāṇī may have tried in v. 18 to induce Vṛṣākapi (her very object of envy) to surrender the Soma offering (to her lord) but he insists on having this oblation.

Indrāṇī may have already (in v. 13) approached Vṛṣākapi's wife with a similar request, if वृषांकपायि means 'Vṛṣākapi's wife'. Failing to rouse the anger of Indra, she may have asked the rich[1] wife of Vṛṣākapi to allow Indra to share in 'her bulls and dear काचित्करं oblation'. If Vṛṣākapi's wife is सुपुत्रा and सुस्नुषा, Vṛṣākapi may well have derided Indrāṇī on account of her barrenness (see v. 9.) "प्रियं कांचित्करं हविः" ' in v. 13 may be a parallel to 'अप्यं हविः प्रियम्' in the previous verse, in which case काचित्करम् may correspond to अप्यंम् and mean

[1]In the offerings she and her lord receive from their worshippers ?

'watery' or better 'cooling'. If Vṛṣākapi's wife has been addressed in v. 13, ते should be connected with उक्षणः &c.—Indrāṇī prays that Vṛṣākapāyī should allow Indra to share in the offerings of bulls and the Soma oblation that she receives (along with her lord). Vṛṣākapāyī probably pays no heed but Indra magnanimously interposes in v. 14 that he is satisfied with only bulls (secondary offerings ?) and is content to go without the Soma (principal offering ?). But Indrāṇī tries in v. 15 to induce a longing for the draught in Indra's mind. In v. 16 she tries erotic inducements but is rebutted in the following verse. In despair, she approaches in v. 18 Vṛṣākapi himself but he too is impervious (v. 19) to her entreaties. Her case is wholly lost and she must have the good grace to show herself reconciled to Vṛṣākapi (vv. 21, 22 or 20-22 below).

Verse 20.—This verse is ascribed by all to Indra. At the mention in v. 19*a* of Vṛṣākapi's motion through the firmament, Indra probably makes here a complimentary reference to that cosmic feat of the solar deity धन्वं च यत्कृन्तत्रं च कतिस्वित्ता वि योजना requires a gerund meaning 'crossing (which)' or a particle meaning 'through (which)' to complete the sense and to connect it with the other half of the verse and I consider this supplying of the ellipsis simpler and more natural than the construction put upon the verse by my predecessors. Griffith translates, "The desert plains and steep descents, how many leagues in length they spread! Go to the nearest houses, go unto thine home, Vṛṣākapi. Supreme is Indra over all." He has but followed Ludwig and Grassmann. He thus annotates on the passage, "Vṛṣākapi appears to meditate flight into distant deserts to escape from the wrathful Indrāṇī. Indra dissuades him, and promises to reconcile Indrāṇī to him." Is this not a far-fetched interpretation? There is no explicit or implicit reference to Vṛṣākapi's flight for fear of Indrāṇī in any of the previous verses.

Why then this assumption of his flight? Verse 18 has shown Indrāṇī suggesting that Vṛṣākapi should receive an offering of animals, slaughtered and duly cooked. Probably an earlier verse (v. 13) contains her pleading to Vṛṣākapi's wife. How can he then still fear her so as to *contemplate* a flight to distant lands? If it be said, that he has *already* left for those regions and is being coaxed now to return as he has no *angry* mother (or step-mother) to meet now, the difficulty about Indrāṇī's address to Vṛṣākapāyī in v. 13 and her reference about Vṛṣākapi in v. 18 remain unaccountable. Verse 19 too, as coming from Vṛṣākapi's lips militates against such an assumption. But if the verse is to be ascribed to Indra, why should he waste words over what he does or does not when his favourite 'son' has to be recalled from voluntary banishment? To connect the two halves of the verse Grassmann uses the conjunction 'therefore' ('drum'). He consequently means that the speaker of v. 20 tries to impress on Vṛṣākapi the frightful character of the way he has chosen and asks him to leave it for a safer land, the land where he has his home. But as Vṛṣākapi has chosen that region (if he has gone there at all) with full knowledge and on purpose—so as to remain safe from Indrāṇī--how can he be induced to leave it through fear? We should expect instead mention of Indrāṇīs present good-will (सौमनस or सुम्न), the only possible inducement.

I therefore supply 'crossing which' or 'through which' to connect the two halves of the verse. I have already referred to I. 35.8 *a,b* 'अष्टौ व्यख्यत् ककुभः पृथिव्यास्त्री धन्व योजना" and mentioned that as a parallel to X 86.20 *a,b* धन्व and योजना are common to both and कृन्तत्रं' if it means 'steep regions', as most interpreters have understood the word, is the exact correspondent of ककुभः (peaks[1]) in I. 35. 8 *a*.

[1]The 'eight peaks' may be eight imaginary hills in the eight directions, whence the later meaning of ककुभ् as दिश्

The obvious conclusion from this correspondence is the solar character of Vṛṣākapi. Geldner[1] has cited I. 35. 8 as parallel but has not realised its necessary implication. If Indra spoke in v. 19, he asks Vṛṣākapi here only to return home after finishing his *daily* course through those deserts and peaks and leagues. But as Vṛṣākapi was more probably the speaker there, Indra now fondly dilates on the great distance his favourite 'son' has to traverse everyday, being reminded of it at its (incidental) mention in v. 19 (**अयमेमि विचाकशत्**).

'नेदीयसः'' :' Sāyaṇa takes as ablative singular but it is better to follow the other interpreters in taking it as adjective to **गृहान्**. **अस्तं** usually means in the Ṛgveda 'house'. But as **गृहान्** is also mentioned here, I prefer to approximate **अस्तम्** to the later meaning of 'setting'—**नेदीयसो गृहान् उप अस्तम् एहि** = 'set and come down towards thy *nedīyas* home.' X. 86 is a very late hymn of the Ṛgveda and a closer connection with classical usage may be expected here. Sāyaṇa and all European interpreters have rendered **नेदीयस्** by 'nearer', but I have followed Tilak in giving it the meaning '*nether*' ('lower')—a meaning for which he seems to have made a strong case[2]. The setting of the sun is apparently his going down and when he sets, he goes to the other part of the earth. The gods were probably conceived as dwelling there. To support this assumption of mine I may refer to I. 35 again—but this time to verses 6 and 7 of the hymn: **तिस्रो द्यावः सवितुर्द्वा उपस्था एका यमस्य भुवने विराषाट् । आणिं न रथ्यममृताधि तस्थुरिह ब्रवीतु य उ तच्चिकेतत् ॥ वि सुपर्णो अन्तरिक्षाण्यख्यद् गभीरवेपा असुरः सुनीथः । क्वेदानीं सूर्यः कश्चिकेत कतमां द्यां रश्मिरस्या ततान ॥** The former verse contains a riddle, which is repeated in the latter. By reading the two verses together carefully the solution of the riddle is easily obtained. Verse

[1] Kommentar, p. 187.
[2] Orion, ch. VII note on R. V. X. 86. 20.

6 declares that there are three heavens (=regions); of them, two are the laps of Savitṛ and are therefore fully illumined by him. The one that is in the region of Yama must needs be the third heaven. What is that? Verse 7 indicates the answer. We have in lines *a* and *b* of this verse reference to the sun's *having traversed* the firmament above us; इदानीम् therefore means 'after that', *i.e.* 'after the sun has set'. The poet wants to be told where the sun shines after he disappears from human sight. Most clearly the sun goes dwon after he sets. The poet most probably believes that the sun's great lamp is not extinguished but shines below this earth[1].

The first two regions are therefore the earth and the heaven above (between which the sun moves) and the third is the world below this earth. That is clearly the region of Yama. If it is the region of Yama, it is also the abode of the gods for देवैः संपिबते यमः (X. 135.1) 'Yama drinks with the gods'. I may mention here the Greek conception of Hades living below the earth and the departed heroes dwelling in bliss in his company. But I am not at all certain that Tilak[2] is justified in localising the third 'foot' of Viṣṇu too below our world. That the sun illumines Yama's region may be an idea peculiar to the poet of R.V.I. 35 alone, for otherwise he would not have thrown out the riddle[3]. As when the

[1] Differently, of course, Aitareya Brāhmaṇa, III. 44: "स वा एष न कदाचनास्तमेति नोदेति तं यदस्तमेतीति मन्यन्तेऽह्न एव तदन्तमित्वाऽथात्मानं विपर्यस्यते रात्रीमेवावस्तात्कुरुतेऽहः परस्तात्। अथ यदेनं प्रातरुदेतीति मन्यन्ते रात्रेरेव तदन्तमित्वाऽथात्मानं विपर्यस्यतेऽहरेवावस्तात्कुरुते रात्रिं परस्तात्। स वा एष न कदाचन निम्रोचतीति ॥ We have here neither an old idea nor a contemporary one but only a dogmatic *innovation* in the usual Brāhmaṇa style.

[2] Arctic Home in the Vedas, p. 331.

[3] I must not also be assumed to accept Tilak's contention (Arctic Home, ch. x. p. 308 ff.) that the Ṛgvedic Aryans knew the earth to be a globe.

sun sets here he goes to dwell in the company of gods. Indra invites Vṛṣākapi to his presence saying: "The deserts. and the steep descents and how many are the leagues thou hast to pass! Through them come down, Vṛṣākapi, to thine home in lower realms." गृह when masculine is used in the plural though the sense may require the singular number. नेदीयसो गृहान् therefore=नेदीयो गृहम्. This nether home is also the abode of Indra (and Indrāṇi). He therefore calls back Vṛṣākapi to the common home after his day's toil through all the upper space. He must have been highly satisfied at Vṛṣākapī's not allowing himself to be caught in the trap set by Indrāṇī (in v. 18).[1]

Note.—All this on the supposition that Indra is the speaker of the verse. But it may be as well put in Indrāṇī's mouth. The only alteration that this would entail is that Indrānī with a good grace becoming(?) of a 'hero's wife' speaks here kind words of welcome to the person she failed to injure. No recalling from banishment need be thrust here even according to this new interpretation.

Verse 21—Geldner in the 'Vedische Studien' ascribed this verse to Indra but in the 'Ṛgveda in Auswahl', he supposes that either Indra or Indrāṇī may be the speaker. Oldenberg follows the latter view but with some uncertainty. Griffith, Sadguruśiṣya and Sāyaṇa make Indra the speaker. Durgācārya (on Nir. XII. 28) makes the impossible assumption that it comes from Vṛṣākapi's lips ('वृषाकपेरार्षम्'). Ludwig supposes Vṛṣākapāvī to be the speaker but what is the necessity for dragging her in here? The verse is certainly in continuation of what has just gone before. If Indra was the speaker there, we may naturally understand him to be the speaker here

[1]This is of course on the assumption, to my mind the more justifiable, that Vṛṣākapi is the speaker in v. 19 and not Indra.

too; and if Indrāṇī was the speaker, it is she who is speaking now. कल्पयावै is in the dual number; therefore two persons must be understood as its subject. They may be Indra and Vṛṣākapi—"सुविता कल्पयावहै" meaning 'we two shall arrange enjoyments for ourselves'; or Indra and Indrāṇī (or Indrāṇī and Indra), the second person, though not actually speaking, being mentally associated—"सुविता कल्पयावहै" now meaning 'we two shall arrange enjoyments for thee'. Indra and Indrāṇī may also be directly conceived as the speakers of this verse. I would, however, personally prefer to take Indrāṇī to be the sole speaker in verses 20, 21 and 22. The dual number in the verb of 21b will be justified by the mental association of Indra. A better view, however, may be that Indrāṇi associates with herself not Indra but Vṛṣākapi's wife Vṛṣākapāyī, if, of course, such a person is referred to in v. 13. In any view, we have here Indrāṇī thoroughly reconciled to Vṛṣākapi. पुनरेहि gives a mere repetition of अस्तमेहि in the previous verse. सुविता (=सुवितानि) is the opposite of दुरितानि. As it is in the plural I have rendered it into English by 'blessed enjoyments' instead of by 'welfare' that would have suited सुवितम् in the singular. य एषः refer to त्वम् understood in the first hemistich. "स्वप्ननंशनः Yāska renders by 'destroyer of sleep'. He writes "स्वप्नान् नाशयस्यादित्य उदयेन". But I have already pointed out that नंशन may have been as well formed from *vnas* 'to attain'; 'bringer of sleep' would then be the meaning of the compound. The derivation and the meaning proposed by Yāska and followed by Sāyaṇa (and Geldner) may also suit the context. The construction will be a little different in the two cases. अस्तमेहि in v. 20 and पुनरेहि in 21*a* could be easily taken, by themselves, to mean 'come back to us, Vṛṣākapi, who hast fled away for fear of Indrāṇī' as some of my predecessors have done. But "य एषः...अस्तमेषि...पुनः" makes this meaning impossible: 'come again, thou, who comest home again'

gives absolutely no sense, if we suppose that Vṛṣākapi has fled away for only once. But if we suppose that Vṛṣākapi is being requested to return home as he does every day, no difficulty arises at all. I therefore take 'अस्तमेषि पथा पुनः to mean ' who comest home again and again by thine olden path'. The beaten track of the sun is frequently referred to; *cf.* ये ते पन्थाः सवितः पूर्व्यासोऽरेणवः सुकृता अन्तरिक्षे। तेभिर्नो अद्य पथिभिः सुगेभी रक्षा च नो अधि च ब्रूहि देव ॥ R. V. I. 35. 11. If नंशन is from √ नश् ' to disappear', the meaning for the second hemistich would be "Thou, killer of sleep (*i.e.* rouser of men from sleep), who comest home again and again (everyday) (after finishing thy day's journey through the upper spaces)." If it is from √ नश् 'to reach', we would have, "Thou, who, bringing in sleep (*i.e.* laying down creatures to rest—cf. 'निवेशयन्नमृतं मर्त्यं च' I. 35. 2*b*) comest home again and again (everyday)." I consider both these interpretations possible but the second more natural.

Verse 22—Ṣaḍguruśiṣya and Sāyaṇa make Indra the speaker of this verse. But as we have इन्द्र in the vocative in the second line he cannot be the speaker here. Geldner supposes that the writer (ऋषिः 'seer') of the hymn is the speaker. This is quite possible but is not altogether certain. Another plausible view is that of Durgācārya, followed by Griffith and with some uncertainty by Oldenberg, *viz.*, that it comes from Indrāṇī. Sāyaṇa has given this as an alternative explanation. Durgācārya and Sāyaṇa, however, make वृषाकपे and इन्द्र refer to the same person (Vṛṣākapi). But how is that possible? 'अजगन्तन' is paraphrased by Yāska(?) in Nir. XIII. 3 as अजगमत. But the termination is certainly that of the active (परस्मैपद) plural (in the second person and plu-perfect tense). We cannot therefore refer it to one person. We have the plural number in Sanskrit when we have more than two persons. But in the present case only two persons have been addressed in

the vocative, Vṛṣākapi and Indra. We should therefore take **अजगन्तन** to be an irregular[1] plural for the dual. Geldner's statement[2] that the plural is used because there are four persons is open to the objection that Indrāṇī and Vṛṣākapāyī have not been addressed here, along with Indra and Vṛśākapi. The objection is, however, not a serious one; for if Indrāṇī can mentally associate Vṛṣākapāyī with herself in v. 21, the seer of the hymn (who is the speaker of v. 22 according to Geldner) can certainly associate in mind Indrāṇī with Indra and Vṛṣākapāyī with Vṛṣākapi. "**उदञ्चः**" Durgācārya explains as in the singular number but Sāyaṇa more sensibly takes it to be in the plural. Here too we must either understand the dual number or make the word adjective to Indra, Vṛṣākapi and their respective wives.

In the previous verse Vṛṣākapi has been welcomed back by Indrāṇī (or Indra) to their common home. '**उदञ्चः**'[3] should therefore mean 'who *were* in the upper heavens' After Vṛṣākapi and Indra reach their home, which is below the earth[4], the earth becomes enveloped in darkness. Hence the poet[5] asks what then becomes of that 'dread beast' who was so long roaming about the firmament. I would again refer to I. 35 (verse 7: **वि सुपर्णो अन्तरिक्षाण्यख्यद्गभीरवेपा असुरः सुनीथः । क्वेदानीं सूर्यः कश्चिकेत कतमां द्यां रश्मिरस्या ततान ॥**). For "**पुल्वघो मृगः**" I have already cited the parallel I. 154.2*b* "**मृगो न भीमः कुचरः**" (said, it should be remembered, about Viṣṇu=Sun). This verse very conclusively establishes that Vṛṣākapi is the Sun. Durgācārya's words on the verse deserve quotation here: "...'**वृषाकपे**

[1]For a somewhat similar irregularity, *c. f.* **हृदयानि नौ** in R.V.X. 85.47*b*

[2]Kommentar, p. 187.

[3]This probably militates against Geldner's view for certainly Indrāṇi and Vṛṣākapāyi had not gone out of the 'house'.

[4]See above on pp. 130-132.

[5]Accepting of course Geldner's view that both 22 and 23 are spoken by the author.

इन्द्र' यदा त्वम् 'उदञ्चः' उदङ्ङेव वर्तमानः प्रदक्षिणं भुवनानि परिगच्छन् 'गृहम्' 'अजगन्तन' गृहानुप्रवेशे हि व्यवधीयते, व्यवधीयते च भगवानस्तं गच्छन्नादित्यः, इत्येतस्मात् सामान्यादुच्यते 'गृहमिन्द्राजगन्तन' इति। तदा त्वयि गृहमुपगते अदृश्ये निरालोको लोकः[1] सहसैव विस्मितो ब्रवीति 'क्व स्यः पुल्वघो मृगः'......" (on Nir. XIII.3). I have no alteration to suggest excepting the substitution of the dual or plural number for the singular in त्वम् etc. The meaning of पुल्वघः' has been already discussed. 'जनयोपनः' Durga renders by जनमोहनः and Sāyaṇa by जनानां मोद–(ह ?)–यिता. 'To delude' is also the meaning of the root युप् according to Pāṇini. Grassmann renders जनयोपनः by 'tormentor of people', Ludwig by 'obstructor of people', Griffith by 'who troubles people', but Geldner following Durgācārya by 'misleader of people'. I cannot suggest any rendering with certainty but I tentatively propose 'charmer of people'.

Verse 23—This verse has been ascribed by Ṣaḍguruśiṣya and Sāyaṇa to Vṛṣākapi and by Ludwig to Vṛṣākapāyī. Griffith makes Indrāṇī the speaker. Oldenberg suggests with some doubt that either Indra or Vṛṣākapi spoke this verse. But I have little hesitation in rejecting all these views and taking the author of the hymn to be the speaker here. I do not however stand alone but I have the support of Professor Geldner[2]. The verse has all the appearance of an author's personal remarks at the conclusion of a poem and I therefore understand it to contain the writer's own words about her[3] own self. The third person constitutes no difficulty for Ṛgvedic poets have referred to themselves as often in the third person as in the first; *cf.* I. 85·11, VII. 33.6 &c., I differ here from Professor Geldner only in the view[4] that the author speaks about Vṛṣākapāyī.

[1]This should make the author speaker here.
[2]Vedische Studien, II. 38.
[3]That the author is a lady will be shown now.
[4]Vedische Studien II. 42,

We often find authors of Rgvedic hymns giving their names in the concluding verses; *cf.* III. 62.18. The name of our author seems to be *Parśu Māṇavī*: it is then a lady who has been pleading so cleverly for the worship of Vṛṣākapi the sun. 'Mānaví' can mean 'Manu's daughter' but the more likely meaning would be here, as usually, 'the woman' or 'the human wife'.[1] Geldner[2] refers to Taittirīya Brāhmaṇa III. 2. 2. 2 for 'Párśu Mānaví' but the reference is without any point. The passage is a *Brāhmaṇa* on the *Mantras* (in Taittirīya Saṃhitā I. 1. 2) in connection with *aśvaparśudhāraṇa.* For "प्रेयमगाद्धिषणा बर्हिरच्छ मनुना कृता स्वधया वितष्टा" in the *Mantra* we have the *Brāhmaṇa* "प्रेयमगाद्धिषणा बर्हिरच्छेत्याह । विद्या वै धिषणा विद्ययैवैनदच्छैति । मनुना कृता स्वधया वितष्टेत्याह । मानवी हि पर्शुः स्वधाकृता ॥" Here 'मानवी हि पर्शुः' is an attempt at explaining मनुना कृता in the Mantra. It should be noted that the word 'पर्शुः, does not occur in the formula. It is धिषणा (*vedi?*) which has been called मनुना कृता in the Mantra; but 'पर्शुः' has been dragged in by the Brāhmaṇa. The only thing that the Brāhmaṇa passage proves is that its author was acquainted with our hymn and tried to interpret the Mantra with words taken from the Rgveda. It is unnecessary to labour the point further, for Professor Geldner has not himself paid any serious heed to the Taittirīya passage in the rendering of R. V. 86. 23*a*[3].

In *Pārśū Mānavī*, 'Mānaví' can hardly be the personal name. 'Párśu' alone can be the name of the writer. But *gotra* names are so often used in Vedic literature instead of personal names, that we cannot be sure that we have not a *gotra* or a clan name here.

[1] Grassmann (Uebersetzung II, 486) renders "Das menschliche Weib, Parçu mit Namen."

[2] Vedische Studien II, 42, Kommentar, 187.

[3] *Cf.* Vedische Studien, II, 28, Glossar, 107, 135.

If it is a *gotra* or a clan name, the connection with Persia naturally suggests itself to one's mind. Ludwig[1] and Weber[2] believe that the word 'Pàrśu' has been used in the Ṛgveda in the sense of Persians. Zimmer[3] has rejected the view but there is neither any inherent improbability in it nor any cogent ground against it. Professors Macdonell and Keith, who seem to follow Zimmer, had to say at least, "At most the only conclusion to be drawn is that the Indians and Iranians were early connected, as was of course the case".[4] It is certain that Ludwig's interpretation of X. 33.2 सं मा तपन्त्यभितः सपत्नीरिव पर्शवः। नि बाधते अमतिर्नग्नता जसुर्वेर्न वेवीयते मतिः ॥" is impossible: पर्शवः here must mean 'ribs,' 'sides'. In VII. 83. 1 'युवां नरा पश्यमानास आप्यं प्राचा गव्यन्तः पृथुपर्शवो ययुः। दासा च वृत्रा हतमार्याणि च सुदासमिन्द्रावरुणावसावतम् ॥" too Parthians and Persians are not referred to. Still, there is at least one passage in the Ṛgveda, *viz.*, VIII. 6.46, where '*Pārśu*' does not mean 'rib' but is a name. In X. 86.23 too 'Pàrśu' is certainly a name. But a *woman* cannot bear the same name as can be given to a *man*. We have therefore a family name or a clan name here and not a personal name. Zimmer[5] says "Pàrśu as a proper name is not at all so rare in Sanskrit that at its occurrence the distant Iranian race must be suggested at once." It is true that Pānini[6] mentions the Pàrśus but they are a tribe of mercenary or fighting people[7]. The Perses are found

[1] Mantralitteratur (Der Rigveda, übersetzt, III) §45.

[2] See Macdonell and Keith's Vedic Index, I, 504.

[3] Altindisches Leben, pp. 135—138.

[4] Vedic Index, I, 505.

[5] Altindisches Leben, 137.

[6] V. 3. 117 "पर्श्वादियौधेयादिभ्योऽणञौ"

[7] Compare Pāṇini v. 3.114. "आयुधजीविसङ्घाञ्ञ्यड्वाहीकेष्वब्राह्मण-राजन्या"

called Parśus or Pa-ar-sus in the Babylonian inscriptions[1] and they were certainly a warlike people who taught their sons "to ride, to draw the bow and to speak the truth"[2]. Cannot Pāṇini's Parśus be connected with these people? Some of the other names in the Gaṇapāṭha under the *Parśvādi* class seem to be of foreign tribes and the Parśus may have been peoples of Iran or living on the outskirts of India proper in Pāṇini's time but there is nothing to show that the Parśu individuals mentioned in the Ṛgveda are foreigners. On the contrary, R. V. VIII. 6.46 proves that the Parśu people were originally identical with or formed a section of the Yādvas=the Yādavas who were one of the five tribes of the Vedic Aryans.

This hymn is addressed to Indra and concludes with a *tṛca* containing, according to the Anukramaṇī, *dānastuti* of Tirindira Pāraśavya. The three verses are: शतमहं तिरिन्दिरे सहस्रं पर्शावा ददे । राधांसि याद्वानाम् ॥ ४६ ॥ त्रीणि शतान्यर्वतां सहस्रा दश गोनाम् । ददुष्पज्राय साम्ने ॥ ४७ ॥ उदानट् ककुहो दिवमुष्ट्राञ्चतुर्युजो ददत् । श्रवसा याद्वं जनम् ॥ ८ । ६ । ४८ ॥ Griffith translates 46 as "A hundred thousand have I gained from Parśu, from Tirindira. And presents of the Yādvās." He makes 'Tiríndira' and 'Párśu' refer to the same person. But his treatment of शतम् and सहस्रं is impossible. The separation of सहस्रम् from शतम् by अहं and तिरिन्दिरे and the balancing of 'शतं .. तिरिन्दिरे' by 'सहस्रं पर्शौ' show that शतम् and सहस्रम् are two distinct objects of आददे and शतम् is not the adjective of सहस्रम्. We should therefore translate with Grassmann, "Presents of the Yadus I have received, a hundred from Tirindira, a thousand from Parśu. This might suggest that Tirindira and Párśu must be two different individuals and Professors Macdonell and Keith[3] have taken this view. But this is not at all necessary. In the following

[1] See the Babylonian text (in Weissbach) of Darius Bisutun, Do. Persepolis and Naksh-i-Rustum.
[2] Herodotus I. 136.
[3] Vedic Index I., 310.

verse some people ('the same Yādvas?') are praised for a gift to Pajra Sāman of three hundred horses and ten thousand cows; both horses and cows (though different in number) come from the same source. We may similarly interpret the previous verse as meaning that one donor gave to our poet (Vatsa Kāṇva) a hundred heads of one species (horses) and a thousand of another (cows). Tirindira and Parśu may be thus identified. The separate mention of the two names need only suggest that Tirindira is the personal name and Parśu the family or clan name. It may not be necessary therefore to reject with Macdonell and Keith[1] the statement of the Śāṅkhāyana Śrauta Sūtra (XVI. 11.20) and of the Sarvānukrama of Kātyāyana (on R. V. VIII. 6, Macdonell's edition, p. 28) that Tirindira was Pāraśavya ('descendant of Parśu'.) Whether we may make Tirindira a Parśu or not याद्वानाम् must be connected (in sense) with both तिरिन्दिरे and पर्शौ. We have therefore a Parśu or the Parśus as Yādava. Sāyaṇa, to be sure, proposes as an alternative interpretation that Parśu Tirindira snatched away the wealth of the Yādavas and gave of it to our poet but probability goes against him. There is no nominative in verse 47; to suit the plural verb ददुः, we must bring in the nearest substantive in plural and that is certainly याद्वानाम् at the end of the previous verse—it is probably the munificence of the Yadus which is being extolled in verse 47. Tirindira Parśu (or say Tirindira and Parśu) eulogised in v. 46 cannot therefore be the enemy (or enemies) of the self-same Yadus. These Yādavas formed an ancient Indo-Aryan tribe, mentioned throughout the Ṛgveda. This should make the Parśus = Perses a section of the Indian community. Professors Macdonell and Keith have admitted[2], "Yadu princes must be meant by

[1] Vedic Index II. 310 and 504.
[2] Vedic Index I. 310-311.

Tirindira and Parśu". If one Parśu is a Yādava, why cannot another (say, the author of R. V. X. 86) belong to the same race? I do not see why we should not derive the Perses of Iran from the Yādavas of India.

The concluding verse of the hymn extolls the gift of one individual, because आनट्, ककुहः ददत् are in the singular number. 'ककुह' means a pre-eminent or excellent animal[1] in R.V.I. 46. 3, I. 181. 5, I. 184. 3, IV 44.2,V. 73. 7 and V. 75.4 and the term has been applied to the Maruts in II. 34.11, to Viṣṇu in III. 54.14, to Indra in VIII. 45.14 and to the Soma juice in IX. 67.8. The word should therefore mean here 'the great one'. Grassmann in his Dictionary (309) puts down the word ककुहः in VIII. 6.48 as meaning 'a prominent animal of the yoke' ('hervorragendes Zugthier') but in his translation (I, 558) he corrected himself to 'great one' (Der grosse). That great one, eulogised as having mounted up to heaven by the very giving of *uṣṭras*[2] yoked in four (to our poet?) should be, according to the context, the same person whose munificence our poet has set out to immortalise. That person is certainly mentioned in the first verse (no. 46) of the *tṛca*. We should therefore read in that verse reference to only one individual.[3] Parśu is thus a family or clan name of Tirindira. A verb has to be supplied in line *c* of verse 48 and that should be उद्दानट् in line *a*. Verse 48 should be translated thus: "The great one has mounted up to heaven by the giving of camels yoked in four and has attained in fame the (entire) Yadu host."[4] The last

[1] Or a prominent or humped animal, say a camel or a humped bull.

[2] Camels; the usual European rendering is 'buffaloes'. See Vedic Index I, p. 104.

[3] Because ककुहः is in the singular.

[4] I have little hesitation in setting aside Grassmann's emendation (übersetzung, p. 558) of जनम् into पशुम्.

portion may be easily taken to mean 'has distinguished himself most among the Yadus', a sense which would very well accord with the context. Here too there is no indication of rivalry or enmity between the patron of the poet and the Yādavas. The greatest objection against taking the Yādavas mentioned in VIII. 6.46 and 48 as inimical to Vatsa Kāṇva's patron Tirindira Parśu (or Tirindira and Parśu) is the fact that the Kaṇvas are the *friends of the Yadus*; *c.f.* R.V. I. 36.18, VIII. 4.7, VIII. 7.18, VIII. 9.14, VIII. 10.5, VIII. 45.27. Sāyaṇa's alternative explanation of verse 46 may therefore be safely set aside. I do not want to deny that some slight distinction is made between Tirindira Parśu and the Yādavas but that is easily explained by taking the prince to belong to a distinct clan of the Yadu race.

R.V. VIII. 6.46-48 is not the only passage which suggests the Parśus=the Perses to be a section of the Yādavas. The word '*Yādva*' occurs four times in the Ṛgveda, in VIII. 6.46 and VIII. 6.48, quoted above, in VII. 19.8 (by the side of "Turvāśam) and in VIII. 1.31. Hymn VIII. 1 contains in verses 1-29 praise of Indra and in the following, 4 verses a *dānastuti*. The four verses are स्तुहि स्तुहीदेते घा ते मंहिष्ठासो मघोनाम् । निन्दिताश्वः प्रपथी परमज्या मघस्य मेध्यातिथे ॥ ३० ॥ आ यदश्वान् वनन्वतः श्रद्धयाहं रथं रुहम् । उत वामस्य वसुनश्चिकेतति यो अस्ति याद्वः पशुः ॥ ३१ ॥ य ऋज्रा मह्यं मामहे सह त्वचा हिरण्यया । एष विश्वान्यभ्यस्तु सौभगासङ्गस्य स्वनद्रथः ॥ ३२ ॥ अध प्लायोगिरति दासदन्यानासङ्गो अग्ने दशभिः सहस्रैः । अधोक्षणो दश मह्यं रुशन्तो नळा इव सरसो निरतिष्ठन् ॥ ३३ ॥ Verses 30 and 31 are to be taken together, otherwise यत् in 31 *a* cannot be properly construed and the sense of 31 remains incomplete and उत ('and') in line *c* becomes meaningless. Besides the liberal patrons enumerated in verse 30, we have undoubtedly another such name in 31 *c,d*. That patron is यो अस्ति याद्वः पशुः' who is Yādva *paśu*'. 'पशुः' Sāyaṇa renders as पशुमान् 'rich in cattle'. But no grammatical justification

can be found for this explanation. Neither is it intelligible how a person who is a descendant of the Yadu race and who knows about priceless treasures and seems to be a liberal donor too can be called a पशु 'a beast.' Mr. Griffith, who rendered the second hemistich of the verse by "For skilled is Yadu's son in dealing precious wealth, he who is rich in herds of kine," felt the difficulty. We therefore read in his notes, "*paśuḥ* which appears to be in apposition with *Yādvaḥ* is hardly intelligible here. Sāyaṇa explains it as *paśuman*, having beasts or cattle, or as a derivative of *paś*, to see, and meaning one who sees what is subtile, *sūkshmasya drashṭā*. Neither of these explanations has anything but Sāyaṇa's name to recommend it, but I adopt the former as a make-shift." I need hardly comment on Sāyaṇa's alternative explanation. Grassmann renders येा अस्ति याद्वः पशुः by 'every man of the Yadu race' but he feels constrained to put a querry mark after 'jeder Mann'. This shows that he too cannot tackle the passage. Geldner (Kommentar 121-2) writes, "*e īdṛsam dhanam ciketati* 1 *eṣa āsaṅgo dātum jānāti* S. But [1] the subject is more likely *paśuḥ* in d, that cattle which the Purohita has received from the Yadu king in addition to horse and carriage". Oldenberg in his Ṛgveda, text kritische und exegetische Noten (Vol. II, p. 74) refers to this interpretation of Geldner but makes the pertinent remark "It seems to me that the verb governs in typical manner a noun in the genitive (c. f. on both V. 73.6; VI 59.5) and has for its subject the patron". Oldenberg himself leans to Ludwig's rendering, which is "While I through faith of the desired (Indra's ?) horse yoked it to the car, then he thinks also of the beautiful treasure, which is the cattle

[1] The 'aber' seems unsjustifiable. Sāyaṇa identifies the *Yādva paśu* with Asaṅga and it is पशुः that he takes as the grammatical subject of चिकेतति

of the Yādava."[1] Against the rendering of the second half I may say that in the two other (VII. 19.8, VIII. 6.46) passages where the word याद्व has been used we have it in connection with persons and not animals and it is doubtful if there is any other certain use of a similar adjective for an animal. I therefore feel inclined to take पशु here as the name of a person. The nearest equivalent that I can think of is पर्शुः There is difference in accent, to be sure, in addition to the want of a *repha* but the word '*paśu*' meaning cattle is at least known to have been accented in two ways, either on the first syllable or on the second. May we not therefore take the पशुः[2] in VIII. 1.31 to be a variant for पर्शुः which was, as I have shown above, a family or a clan name? If this suggestion can be accepted, the connection between the Parśus (=Perses) and the Yādavas suggested by VIII. 6.46 receives a confirmation.

I therefore consider the Persians of Iran to be the Parśus, a section of the Yādavas of India, who migrated from this land in post-Ṛgvedic times. Pāṇini's Parśus may have been, as I have already said, Iranian Persians; but they could also be such descendants of the old Yādava Parśus as might still be in India for the Satvats, an undoubted Indian tribe, belonged, according to the Ganapāṭha as we have it to the पर्श्वादि class (Pā. V. 3. 117). The Baudhāyana Śrauta Sūtra (XVIII. 44) makes the Parśus[3]

[1] Ludwig, Der Ṛgveda, II, 171, "Weil ich vermöge des glaubens des verlangenden [Indra's ?] rosse an den wagen brachte, 1 da denkt er auch an das schöne trefliche, was das vieh des Yādava ".

[2] Can the loss of the *repha* be accounted for by the shifting of the accent to the following syllable ?

[3] Caland in his "über das Rituelle Sūtra des Baudhāyana" (p. 36) gives the name as *Sparśu* but he puts a querry mark after it. In his Bibliotheca Indica edition of the text (p. 397) too he prints the name as *Sparśavaḥ*. The Vedic Index (II, 489, article 'Sparśu') but follows Caland's statement in the pamphlets "über das &c.," But the *s* most obviously belongs to the preceding

along with the Gāndhāris and the Arāṭṭas, descendants of Urvaśī and Purūravas, settled in the west. These Parśus may well be a section of the Yādavas who in Epic and Puranic times were settled in the west of India. So when Zimmer [1] objects that the Pāraśavas were a people to the south-west of the Madhyadeśa, I cannot believe that the connection of the Iranian Persians with them is made impossible; for we can think that the Parśus (=Perses) were originally Indians (a community of the Yādavas) and migrated to Iran from India in later times. As regards Manu's [2] derivation of the Pāraśavas from a fusion of Brahmin males with Śūdra females, referred to by Zimmer, is it necessary to pay any serious attention to the fictions about the origins of the mixed (?) castes indulged in by these *cāturvarṇya* theorists?

When I say that the Persians may have originally migrated from India, I do not for a moment want to suggest that the whole Aryan population of Iran was derived from that source. The Medians may have come from the same place from which came the Indo-Aryans themselves. There is, so far as I can understand now, no

word *Gāndhārayaḥ* and is the *sandhi* substitute for the *Visarjanīya*; *Parśavaḥ* must therefore be the spelling of the second name. The passage runs as "सा (Urvaśī) आयुं च अमावसुं च जनयां चकार । सा होवाचेमौ बिभृतेमौ सर्वमायुरेष्यत इति । प्राङायुः प्रवव्राज तस्यैते कुरुपञ्चालाः काशिविदेहा इत्येतदायवं प्रव्राजम् । प्रत्यङ् अमावसुः तस्यैते गान्धारयस्पर्शवोऽराट्टा इत्येतदामावासवम् ॥ The statement of the Baudhāyana Śrauta Sūtra does not make the Parśus Yādavas, if we *must* follow the Purāṇic genealogies according to which Yadu was descended from Āyu, whereas according to Baudhāyana the Gāndhāris, the Parśus and the Arāṭṭas are descended from Amāvasu, brother of Āyu. But the testimony of the Purāṇas is by no means unimpeachable. In any case, the B. S. S. does make the Parśus (=Persians ?) descended from old Indo-Aryan families.

[1] Altindisches Leben, 137.

[2] यं ब्राह्मणस्तु शूद्रायां कामादुत्पादयेत्सुतम् । स पारयन्नेव शवस्तस्मात् पारशवः स्मृतः । IX, 178.

historical[1] difficulty in deriving the Perses alone from India and in almost historical times. The Perses are not mentioned in Babylonian or Assyrian inscriptions till the 8th century B. C.,[2] whereas the Medes receive this mention as early as the 28th centuary B.C.[3]. This may be simply due to the Persians and the Medians having entered Iran from different places and in different ages. Further discussion of the question in the light of ascertained facts will be out of place here and I must reserve that for a later treatment.[4]

After this long (but necessary) digression, let us see what the Parśu lady has got to say about herself in X. 86. 23. She says that she has produced twenty children at one birth and that though her burden had caused her pain, it is good that has come out of it. What can this mean ? Giving birth to twenty children all at once is humanly impossible, for two is the maximum number a human mother can bring forth at one time. We must therefore search for some mystic meaning here. This we are fully entitled to do for there is plenty of mysticism in the extant Vedic text of this period. I may only mention here R. V. I. 164. Now, what has gone before has made it abundantly clear that the writer of the hymn is a champion of the worship of Vṛṣākapi. She may therefore be

[1] I shall not touch here the linguistic side of the question.

[2] See F. Hommel, Geographie and Geschichte des alten Orients Part 1, p. 197, Hall's Ancient History of the Near East and Ragozin's Media, p. 274. But there is a differenece of opinion among scholars as to whether Parsua (near the Zagros) mentioned in the annals of Sargon II was inhabited by the Perses ; see Eduard Meyer in Encyclopaedia Britannica (11th edition), XXI, 253. If Meyer is right, the earliest inscriptional mention of the Persians would be in the time of Cyrus (6th century B. C.)

[3] E. Forrer, in Z. D. M. G., New Series, Vol. I, p. 247, P. Giles has followed him in Cambridge Ancient History, Vol. II (p. 15) recently published.

[4] I may, however, mention here that it is possible that when after the demise of Kṛṣṇa there was a disperson of the surviving Yādavas, some of the Yādava tribes migrated outside India. The Parśus may have now found their way to Iran. Compare Viṣṇupurāṇa V ch. 38, vv. 5-34, particularly vv. 12-28 where it is described how Kṛṣṇa's seraglio was attacked and carried away by Ābhīras in the Panjab.

conceived as occupying the same positition in this worship as that of Indrāṇī in the case of Indra's worship: she may have looked upon herself as the human spouse of Vṛṣākapi (the sun). *Vṛṣan* often means in the Ṛgveda, as I have pointed out above, 'potent' 'saturating', 'impregnating'[1]. *Vṛṣākapi* is formed from this word. Our potent Vṛṣākapi would certainly make his earthly spouse fruitful, so much so that 20 children could issue at one birth. We can now guess what animal this god has been conceived as. It is the sow which can give birth to such a large number of children in one conception. If Parśu Mānavī conceives herself as a sow her Divine Lord would be the Boar. This certainly suits our hymn. The dog or the hunter that Indrāṇī threatened to let loose at Vṛṣākapi in v. 4 above has been called वराहयु 'hunter of the boar'; therefore its (or his) victim would be a boar. A boar can certainly be called a dread (or voracious) animal (v. 22*c*). *Kapi* = 'tawny-coloured' constitutes no difficulty, for a tawny-coloured boar is not an impossibility.[2] Gods have been likened to boars in the Ṛgveda. In IX. 97.7 Soma has been called a *Varāha*. In X. 67.7 "स ईं सत्येभिः सखिभिः शुचद्भिर्गोधायसं वि धनसैरदर्दः । ब्रह्मणस्पतिर्वृषभिर्वराहैर्घर्मस्वेदेभिर्द्रविणं व्यानट्" the Maruts have been called 'strong (or potent) boars.' The combination of वृषभिः with वराहैः should be particularly noted. In I. 114.5 "दिवो वराहमरुषं कपर्दिनम् &c.", said about Rudra, the character of a *varāha* and the ruddy colour have been combined in one individual. The name वराहु has been given to the Maruts in I. 88.5 and to Vṛtra in I. 121.11. It is possible that the sun has been meant by वराहम् in X. 28.4. I can therefore feel little hesitation in understanding Vṛṣākapi to be poetically conceived

[1] Compare II. 35.13. स ईं वृषाजनयत्तासु गर्भम् etc.

[2] I knew of such an animal, possessed by our college *Mahtar* at Rangpur.

not as an ape but as a boar. The Vedic sun god Viṣṇu has been described in the later Purānas as having taken the incarnation of a boar. For the Vedic source of this legend, I may simply refer my readers to Macdonell's Vedic Mythology, pp. 41 and 151.

If the Parśu lady looks upon herself as the spouse of the Divine Boar, we have a case of clear *erotic mysticism.* I now draw the attention of my readers to two facts that we have discovered (1) the solar character of the object of this erotic worship and (2) the Yādava nationality of the Parśus (and therefore of our poetess who lent herself to this sort of worship). We know that Kṛṣṇa the Yādava hero was in later times identified with the old Sun-god Viṣṇu and that an erotic cult grew up around his figure. On the former point we have sufficient light already and Dr. Hemchandra Roy Chaudhuri has brought together in his Early History of the Vaiṣnava sect (Lecture I) all the available evidence on the point. But how or whence the erotic mysticism came in was as yet obscure. The Vṛṣākapi hymn as we have how understood it, may throw much light on the problem. We have in this hymn a clear instance of the erotic worship of the sun. It is with this sun (Viṣṇu) that Kṛṣṇa was identified and the erotic cult may well have come from the same source from which came Kṛṣna's connection with the 'cows' '(*go*='rays of the sun' or waters ?) and the other solar phenomena of the human god.

Now one may legitimately object that such far-reaching conclusions should not be drawn from a single passage. But I reply that I have proceeded on parallels and I recount them here. As regards the clash between two cults or the pleading for a particular god, I may refer to R. V. I. 165 and IV. 42, two early hymns, and I. 170, a hymn of about the same age as

X. 86[1]. R. V. IV. 42 describes a contest between Varuṇa and Indra as to who is superior. The author prudently decides in favour of both (vv. 9 and 10) but there are sufficient indications of a personal leaning towards Indra (cf. v. 8)[2] In. I. 165 we have a quarrel between Indra and the Maruts who are his allies in the fight with Vṛtra. The hymn "appears to be, as Wilson observes, a vindication of the separate, or at least preferential worship of Indra, without comprehending at the same time, as a matter of course, the adoration of the Maruts"[3] Indra and the Maruts have contended for the superior position but the latter had finally to yield to the former. I. 170 which is ascribed to the same Agastya but is probably by a later hand (a descendant of Agastya?) shows Agastya pleading to Indra for allowing him to worship (with impunity) Indra's friendly host, the Maruts. In R. V. X. 124 too we have probably a preference shown to Indra over Varuṇa. In the light of these passages we may safely read in X. 86 an apology for the preferential worship of the Sun-god, but to the exclusion this time of the national god Indra. We know that Indra lost his glory in later times and his place was occupied by Viṣṇu and the other Purānic gods. R. V. X. 86 shows a transition to this. Indra is still the national god here and that necessitated the diplomatic language of Vṛṣākapi's apologist. The sun was worshipped by the Aryans in various forms even in the earliest times but its prominence was a late phenomenon. The transition can be easily marked but this would not be a proper place for such an attempt. We have in X. 86 the sun-worship

[1]See Arnold's Vedic Metre pp. 273,276 and 287.

[2]This would remined us of Bloomfield's plausible view about the position of Varuṇa in the Ṛgvedic age.

[3]Griffith, Hymns of the Ṛgveda, 2nd Edn. I. 228n.

not only given a prominence but possessing an exclusive character too. Of course the conditions of the time required that the new cult should be sanctioned by Indra.

For the erotic mysticism my chief parallel would be VIII. 80 (Max Müller's VIII. 91). As this hymn is very important from my point of view, I shall quote it in full and then discuss the pertinent portions. The hymn runs as

कन्या॒ ३ वारवाय॒ती सोम॒मपि॑ स्रु॒ताविदत् ।
अस्तं॒ भरन्त्यब्रवीदिन्द्रा॑य सुनवै त्वा शक्राय सुनवै त्वा ॥ १ ॥
असौ य एषि वीरको गृहंगृहं वि॒चाकशत् ।
इमं जम्भसुतं पिब धानावन्तं कर॒म्भिणमपूपवन्तमु॒क्थिनम् ॥ २ ॥
आ च॒न त्वा चिकित्सामोऽधि च॒न त्वा नेमसि ।
शनैरिव शन॒कैरि॒वेन्द्रायेन्दो परि॑स्रव ॥ ३ ॥
कु॒विच्छकत्कु॒वित्करत्कु॒विन्नो वस्यसस्करत्
कु॒वित्पति॒द्विषो यतीरिन्द्रेण स॒ङ्गमामहै ॥ ४ ॥
इमानि॒ त्रीणि विष्टपा तानीन्द्र॒ वि रोहय ।
शिरस्त॒तस्योर्वरा॒मादि॒दं म॒ उपोदरे ॥ ५ ॥
असौ च॒ या न उर्वरादि॒मां त॒न्वं१ मम ।
अथो त॒तस्य॒ यच्छिरः सर्वा ता रोम॒शा कृधि ॥ ६ ॥
खे रथस्य॒ खेऽनसः खे युगस्य शतक्रतो ।
अ॒पा॒लामि॑न्द्र॒ त्रिष्पूत्व्यकृणोः सूर्यत्वचम् ॥ ७ ॥

The following legend has been told by Sāyaṇa in connection of this hymn:—पुरा किल अत्रिसुता अपाला ब्रह्मवादिनी केनचित्कारणेन त्वग्दोषदुष्टा सती अत एव दुर्भगेति भर्त्रा परित्यक्ता पितुराश्रमे त्वग्दोषपरिहाराय चिरकालमिन्द्रमधिकृत्य तपस्तेपे। सा कदाचिद् इन्द्रस्य सोमः प्रियकरो भवति तम् इन्द्राय दास्यामीति बुद्ध्या नदीतीरं प्रत्यागमत्। सा तत्र स्नात्वा पथि सोमममप्यलभत तमादाय गृहं प्रत्यागच्छन्ती मार्ग एव तं चखाद। तद्भक्षणकाले दन्तघर्षणजातं शब्दं ग्राव्णां सोमाभिषवध्वनिमिति मत्वा तदानीमेवेन्द्रः समागमत्। आगत्य तामुवाच किमत्र ग्रावाणोऽभिषुण्वन्तीति। सा प्रत्यूचे अत्रिकन्या स्नानार्थमागत्य सोमं दृष्ट्वा तं भक्षयति तद्भक्षणजो ध्वनिरेव न तु ग्राव्णां सोमाभिषवध्वनिरिति। तथा प्रत्युक्त इन्द्रः पराङावर्तत। गच्छन्तमिन्द्रं सा पुनरब्रवीत्। किमर्थं निवर्तसे त्वं तु सोमपानाय गृहं गृहं प्रति

गच्छसि तदिदानीमत्रापि मम दंष्ट्राभ्यामभिषुतं सोमं पिब धानादींश्च भक्षयेति। सैवमिन्द्रमनाद्रियमाणा सती पुनरप्याह अत्रागतं त्वामिन्द्रमिति न जानामि त्वयि गृहमागते बहुमानं करिष्यामीतीन्द्रमुक्त्वा अत्र समागत इन्द्र एव नान्य इति निश्चित्य स्वास्ये निहितं सोममाह हे सोम त्वमागतायेन्द्राय पूर्वं शनैः ततः शनकैः क्षिप्रं परिस्रवेति। तत इन्द्रस्तां कामयित्वा तस्या आस्य एव दंष्ट्राभिषुतं सोममपात् तत इन्द्रेण सोमे पीते सति त्वग्दोषादहं भर्त्रा परित्यक्ता सती इदानीमिन्द्रेण संगता इति अपालायामुक्तायामिन्द्रस्तां व्याजहार। किं कामयसे तदहं करिष्यामीत्युक्ते सा वरमचीकमत। मम पितुः शिरो रोमवर्जितं तस्योषरं क्षेत्रं फलादिरहितं मम गुह्यस्थानमप्यरोमशम् एतानि रोमफलादियुक्तानि कुर्वित्युक्तायां तत्पितृशिरःस्थितां खलतिमपहाय क्षेत्रं च फलादियुक्तं कृत्वा एतस्यास्त्वग्दोषपरिहाराय स्वकीयरथच्छिद्रे शकटस्य युगस्य च छिद्रे एतां त्रिवारं निश्चकर्ष। तस्याः पूर्वाभिहतायाः त्वक् शल्यको द्वितीया गोधा तृतीया कृकलासोऽभूत्। तत इन्द्रस्तामप्यपालां सूर्यसदृशत्वचमकरोदित्यैतिहासिकी कथा॥

Sāyaṇa says that his authority is the Śāṭyāyana Brāhmaṇa which he has quoted from in the course of his comments on the different verses. It seems that Sāyaṇa has freely drawn on his imagination in supplementing the statements in that Brāhmaṇa. The Brāhmaṇa story is somewhat shorter. Śaunaka in his Bṛhaddevtā (VI. 99-107 Macdonell's Edition) gives a similar story.

I do not give any translation of the hymn as none is needed. Besides, Sāyaṇa's full note will be found sufficient to remove all difficulties. But his absurdities will require to be pointed out and discussed. Sāyaṇa makes her a married woman but neither the Śāṭyāyana Brāhmaṇa nor the Bṛhaddevatā suggests any such thing. We have in the hymn itself explicit statement (in v. 1) that Apālā was a कन्या = a virgin. Sāyaṇa's supposition, as Oldenberg rightly points out[1], is due to his misunderstanding of the word पतिद्विषः in v. 4. Sāyaṇa renders it by पत्या द्विष्टाः, but the accent is that of a Tatpuruṣa compound and not of a Bahuvrīhi. Therefore 'haters of husbands' should be its real meaning. Apālā

[1] Ṛgveda, textkritische und exegetische Noten II, 142.

is a virgin and lives in her father's house, because where else would a maid live? Hence her solicitations for hair on her dear father's head and for crops in his field (vv. 5 and 6) and for the general prosperity of the family (v. 4 *a* and *b*). One thing stands out quite clear in the hymn and in its different interpretations, *viz.*, the erotic relation between Apālā and Indra. Apālā's love relations with Indra are manifest from 4 *d* (इन्द्रेण सं गमामहै) 5 *d* and 6 *b* and have been fully brought out by Sāyaṇa, Śaunaka, the author of the Śāṭyāyana Brāhmaṇa, Oldenberg and Geldner. The desire expressed in 5 *d* and *b* for "crops of hair below my waist", can only mean the attainment of sexual powers and this can have, in the present context, significance only in an erotic[1] relation with Indra; for otherwise 4 *d* becomes meaningless. There is no reference in the text to any skin disease which Śaunaka and Sāyaṇa[2] have unnecessarily[3] dragged in.

One important point that deserves notice here is the plural in नः, वस्यसः, पतिद्विषः, यतीः and संगमामहै in v. 4. Sāyaṇa's "सर्वत्र पूजार्थे बहुवचनम्" is to be set aside without any hesitation. The plural suggests that Apālā does not stand alone in her love relations with Indra but belongs to a class of women who hating the taking of husbands remain virgins and worship Indra as their lover instead. That the love relation with Indra is not earthly but is mystic is made probable by 2 *b* and 3. Apālā wants the Soma she is pressing with her teeth to flow slowly, very slowly, that she may get ample time to

[1] Or more correctly 'erotic-mystic'; see below.

[2] The last two sentences in Sāyaṇa's comments on v. 7 probably come from Sāyaṇa and not from the Śātyayana Brāhmaṇa.

[3] Probably सूर्यत्वचम् in v. 7 suggested to them that Apālā had skin disease before.

know her lord fully. It is then during the pressing and flowing of the Soma in her mouth that she has communion with her divine lover. Something like spiritual ecstasy must be meant by this communion. Persons acquainted with the later[1] mystic literature of India will fully realise the force of my remarks. I may here incidentally draw the attention of my readers to a new German publication "Die Anfänge der Yogaproxis (eine Untersuchung über die Wurzeln der indischen Mystik nach Ṛgveda and Atharvaveda)" by Dr. J. W. Hauer, Privatdozent at Tübingen, who had come out to India to study yogic practices. Dr. Hauer[2] has read in this passage an ecstatic relation between Apālā and Indra through the medium of Soma. My difference with him lies only in my emphasising the erotic character of this mysticism.

Śaunaka (Bṛhaddevatā VI. 107) considers R. V. VIII. 80 to be an *Aindra* hymn and not an *Itihāsa* hymn as Yāska and Bhāguri hold. It does not contain a mere tale about Indra and his human love, but has Indra for its "deity". We may very reasonably infer from this hymn that Indra was worshipped by some females (who remained unwedded) as their divine lover or husband. It is probably thus that the erotic verse (34) at the end of VIII. 1 is to be explained. Indra has been behymned in vv. 1-29 and the अस्य in v. 34 *a* may refer to him. That शश्वती is not a proper name but means 'every' is certain[3]. May the two verses at the end of I. 126 be similarly interpreted? One would be naturally reminded of the Purāṇic story of Indra's amour with Ahalyā.[4]

[1] This hymn too is a very late one. See Arnold, Vedic Metre, p. 283.
[2] Pp. 137, 138 of his book.
[3] See Macdonell and Keith, Vedic Index I, 70.
[4] Is she the same as our Apālā? The story of Kubjā (Viṣṇupurāṇa V ch. 20 vv. I—12 and else where) was certainly suggested by that of Apālā.

I may now return to the Vṛṣākapi hymn. The hymn shows as I have indicated above that Sun-worship was supplanting the worship of the old national deity Indra, at least in the Parśu=Yādava community. Along with the chief character the other attributes of Indra also may have been usurped by this god and the Yādava ladies may have taken to the worship of the Sun-god as their divine lover. Now, later Vaiṣṇavism (the Vāsudeva cult) rose in this very community. The national hero of the Yādavas, Vāsudeva Kṛṣṇa Devakīputra, came to be identified with the old Vedic Sun-god Viṣṇu and worshipped as the Supreme Being. Readers of the Purāṇas will remember that the boy Kṛṣṇa stopped the worship of Śakra (Indra) among the cowherds in whose community he grew up[1]. This may be due to a reminiscence of the Sun-worship (later substituted by the worship of Kṛṣna identified with the Sun) ousting the old Vedic Indra-cult in the community of the Yādavas. It appears from the words of Megasthenes that there was some contrast between the worshippers of Herakles and the worshippers of Dionysus in India. I have recently[2] shown that by the cult of Dionysus we are to understand the general Vedic sacrificial cult. As Kṛṣṇa (identified with Viṣṇu) was later installed in the place of Indra, the erotic worship associated with that god may well have come over to him. It is probably thus that we read in some of the Purānas stories of Kṛṣṇa's amorous sports with the cowherd girls. This may not be the creation of pure fancy but may be a half-true account of what was perhaps actually in vogue

[1] I am indebted to my friend Professor Gour Govinda Gupta, M.A. of the Rangpur College for drawing my attention to this point. See Viṣṇupurāṇa (V. ch. 10). Compare also the story of Kṛṣṇa's snatching away of the Pārijāta and the consequent fight with Indra (Viṣṇupurāṇa V. ch. 30 and elsewhere).

[2] In a paper on "Dionysus in Megasthenes; who was he?" written for the Madras Oriental Conference.

in Kṛṣṇa's community—prior to his birth and subsequent to it. Space forbids my dilating further on the point and I must reserve a detailed history of how the Rādhā-Kṛṣṇa cult grew up for a future treatment.

The Vṛṣākapi hymn, when studied with some other hymns of the Ṛgveda thus lights up many obscure points in the history of Indian religious ideas and practices. We have also incidentally learnt that the Persians of Iran may have come from the Yādava community of India. The Yādavas, as I have tried to indicate, were probably exclusive worshippers of the Sun. Mithraism that very much spread in Iran in historical times may possibly be due to the Parśu = Yādava element in the Iranian population. Whether the erotic mysticism of the later Persian Sufis is due to that original Yādava element or to recent borrowings from western India or to independent development I must leave undetermined for the present.

P. S.—A friend of mine in Benares (Pandit Nārāyaṇa Śāstrī Khiste Sāhityacārya of the Government Sanskrit College Library) objects that the erotic mysticism brought out above belongs really to *Āgamic* (Tāntric) culture and is not *Nigamic* (Vedic) in character. I do not want to make any pronouncement on the point, this way or that way, *now*. Probably what I have said above leaves the question undetermined. I have only said that the cult of Vṛṣākapi as such has no necessary (or even likely) Dravidian origin: We have erotic mysticism associated with the Aryan national god Indra too (and its development can probably be traced from very early times). At any rate, what I have sought to establish is not exactly Vedic character of erotic mysticism but its existence in late Ṛgvedic times. Though the hymns discussed above are some of the latest in the Ṛgveda, some of their verses (and therefore the hymns themselves ?) are early enough to find place in the Taittirīya collections and all these hymns have been analysed by Śākalya. The above discoveries raise important issues about the relation between Vedic and Tāntric (or Pañcarātric) cultures which I intend to pursue now. But I must be assured by scholars first that I have set out on a right track. सत्यमेव जयतात्.

APABHRAMS'A LITERATURE

HIRA LAL JAIN, M.A., LL.B.

Research scholar.

§1. A systematic study of the classical languages of India as a branch of oriental learning commenced only a little over a century and a quarter ago, after the epoch-making announcement of Sir William Jones in 1783 regarding the importance of Sanskrit literature. What attracted the notice of scholars then was classical Sanskrit, chiefly the *kāvya* literature.

Vedic literature was the next to arouse their interest, and it was not till within the last fifty years that Prākṛit literature came to be recognized as an equally important branch of these studies. The late appearance of Prākṛit literature in the field was mainly due to the fact that the chief custodians of this literature—the Jainas—until very recently, did not care to publish it. It has, of old, been almost a monopoly of the Jainas to write in Prākṛit just as it was, to a certain extent, a monopoly of the Brahmaṇas to write in Sanskrit, and of the Bauddhas to write in Pāli. Prākṛit writings of the Brahmaṇas, rare and fragmentary, are to be found mostly in the Sanskrit dramas, but these do not truthfully represent the Prākṛit language prevailing at any particular period. These writers were well-versed in Sanskrit only and Pt. Chandra Dhara Śarma Guleri is right in saying that their Prākṛit is mostly imitation reproduced from Sanskrit models in conformity with the rules of Prākṛit grammar, substituting '*ya*' for '*ta*' and '*kha*' for '*ksha*'.[1] The Jainas, on the other hand, cultivated the Prākṛit languages as their media of instruction

[1] *Nāgarī Prachāriṇī Patrikā* Vol. I, p. 8.

and composition. Hence the various Prākṛits, mentioned and defined in works on dramaturgy, rhetorics and grammar, are profusely and faithfully illustrated in the writings of the Jainas. The only surviving specimens of Māgadhî and Ardha Māgadhî Prākṛits are the canonical Sūtras of the Śvetāmbara Jainas. Mahārāshṭrî Prākṛit, which came to command a good literature even in the early centuries of the Christian era, as is evident from Hāla's anthology and the *Setubandha* of Pravarasen, has been utilised by the Jainas in the composition of commentaries on the canonical works as well as in other sacred and narrative writings. Śaurasenî Prākṛit is best represented by the Digambara Jaina works such as those of Kundakundāchārya, Swāmî Kārttikeya, Vaṭṭakera, Nemichandra Siddhānta Chakravarttin and others. Paiśāchî has indeed not found any favour with the Jainas, and it unfortunately has no literature existing. The only work in the language, Guṇāḍhya's *Bṛihat kathā*, has long disappeared. What little we can know of it to-day is from works on poetics and grammar. Of the Apabhraṁśa Prākṛit, however, which is closely akin to the Paiśāchî, a good deal of literature has come down to us, chiefly, through the Digambara Jainas. The object of this article is to show how much literature of this language has so far come to light.

§2. References to Apabhraṁśa language are to be found in the works of rhetoricians and grammarians ranging from Pātañjali (2nd cent. B.C.) to Mārkaṇḍeya (17th cent. A.D.)[1]. These references prove that Apabhraṁśa existed, as a dialect chiefly of one Ābhîra people, about the beginning of the Christian era, that by the 6th century A.D., it had developed a literature of its own, which had to be recognised by rhetoricians like Bhāmaha and Daṇḍin, and that by the 11th century it came to command a rich and varied literature and writers on rhetorics and grammar also began to

[1] Introduction to *Bhavisayattakahā* G. O. S. XX.

distinguish varieties in the language. Of the grammarians Hemachandra, who lived in the 12th cent. A.D., is the most important in this matter. He is the first to treat of the language with some thoroughness giving copious illustrations from works to which we have now no access. Later grammarians, such as Trivikrama, Lakhshmīdhara and Simharāja, have only copied Hemachandra even in the matter of giving illustrations. It is only Mārkaṇḍeya, who, in his Prākṛit Sarvasva, has shown some independence in this respect.

§3. The chief characteristics of the Apabhramśa language, as understood from the works that will presently be noticed, are the following:—

1. Morphology has changed to a great extent. Many of the case and conjugational signs have disappeared, and the remaining ones are irregularly used. The language shows a clear tendency to become non-inflexional.

2. Vocabulary has become enriched with the importation of many rare, colloquial and provincial words, for which, strictly speaking, no Sanskrit equivalents can be found.

3. Many new poetic measures appear. In other *Prākṛits* we do not usually meet with verses composed in metres other than the Āryā or the classical Sanskrit metres. But in Apabhramśa, numerous new metres came to be used, based, not upon the number of syllables in each foot as in classical Sanskrit, but upon the quantity of accent or *mātrās* as in the Vedic poetry. Definitions and illustrations of these numerous new measures are to be found in '*Prākṛit Piṅgala*.'

4. Verses are characterised by rhyme which appears here in Indian poetry for the first time[1].

[1] The only kind of versification, resembling rhyme and found in classical Sanskrit, is furnished by the figure of speech called *Pādānta yamaka* (*Cf.* Daṇḍin's *Kāvyādarśa*, chapter III, paragraphs 41—44). It is very likely that rhyme grew out of this figure of speech.

These four tendencies we find fully manifested in the modern vernaculars of India such as Hindī, Gujrātī, and Mārwārī. Apabhraṁśa language thus forms a connecting link between the older Prākṛits and the modern vernaculars. Hence the literature is of very great importance for the philology of these vernaculars.

§4. Just a decade ago it was hardly known that there was much literature existing on the Apabhraṁśa language. What was then known of this literature to scholars was found in the Fourth Act of Kālidāsa's *Vikramorvaśī*, in the *Prākṛit Piṅgala*, in Hemachandra's Grammar and his *Kumārapāla charita*, in Sanskrit works on poetics such as *Sarasvatī kaṇṭhābharaṇa* and the commentaries to *Daśarūpa* and *Dhvanyāloka*, and lastly in the. Jaina legends like the *Kālakāchārya Kathā*, *Prabandha Chintāmaṇi*, *Vetāla pañchaviṁśatikā* and *Siṁhāsanadvātriṁśikā*. Some of these works have been utilised by Pischel in his Prākṛit grammar.

The first complete work of Apabhraṁśa, brought to light and ushered into modern studies, is the *Bhavisayattakahā* of Dhanapāla published by Dr. Jacobi in 1918, with text in Roman characters and an introduction in German, and again in the Gaekwāḍa Oriental Series No. XX. In the introduction of this latter edition, we find notice of fourteen entire works of Apabhraṁśa, almost all of which are awaiting publication[1].

§5. Among the works noticed in the introduction to *Bhavisayatta kahā*, what seems to me to be of the greatest importance both on account of its age as well as extent is the *Tisaṭṭhimahāpurisaguṇālaṅkāra* of *Pupphadanta*. Dr. P. D. Gune, the writer of the introduction, saw only an incomplete manuscript of the

[1] Of these the only work that I know to have been published is the *Paramātma Prakāśa* of Yogīndra Deva.

work, containing only twenty-seven *sandhis* (chapters). The work, however, is completed in 102 *sandhis* equal to about 13000 *ślokas*[1] in extent and is divided into two parts called the *Ādipurāṇa* and the *Uttarapurāṇa*. Its subject-matter is the same as that of Jainasena's and Guṇabhadra's Sanskrit works of the same names. Even a cursory examination of the work[2] has revealed much information about the author and his date. The poet prefaces his work with narrating to us the circumstances that brought about its composition. We find the poet resting in a garden of *Mewāḍi* (*Melapāṭī* or *mānyakheṭa*), fatigued with a long journey and injured at heart with insult of some kind meted out to him we know not where. Two persons, residents of the city, approach him, and they introduce him to Bharata the minister of king Śubhatuṅgadeva (Vallabharāya). Bharata keeps him in his own mansions and, recognising his poetic talents, induces him to write the '*Mahāpurāṇa*'[3].

[1] Thirty-two syllables are counted to make one *śloka* which is the usual measure to calculate the extent of a work.

[2] I saw a complete MS. of this work as also of the other works of Pushpadanta to be noticed presently, in the *Balātkāragaṇa Jain Bhandār* of Kāranjā (Akola district, Berar). For other MSS. of the work and a detailed information about the author cf. Pt. Nāthū Ram Premi's article in *Jaina Sāhitya Saṁśodhaka* Vol. II. No. 1. p. 57.

[3] तं कहमि पुराणु पसिद्धणामु, सिद्धत्थवरिसे भुवणाहिरामु ।
उव्वद्धजूडु भूभंगभीसु, तोडेप्पिणु चोडहो तणउ सीसु ॥१॥

भुवणेक्करामुरायाहिराउ, जहिं अच्छइ तुडिगु महाणुभाउ ।
तं दीणदिण्णधणकणयपयरु, महि परिभमंत मेवाडि नयरु ॥२॥

अवहेरिय खलयणु गुणमहंतु, दियहेहिं पराइउ पुप्फयंतु ।
दुग्गमदीहरपंथेणरीणु, णव इंदु जेम देहेण खीणु ॥३॥

तरुकुसुमरेणुरंजियसमीर, मायंद गुंछ गुंदलिय कीर ।
णंदणवणे किर वीसमइ जाम, तहिं विण्णि पुरिस संपत्तताम ॥४॥

The poet shows his gratitude to his patron by mentioning him in the colophon of each *sandhi* of his epic and praising him at many places. Pushpadanta was a

पणवेप्पिणु तेहिं पवुत्त एव, भो खण्ड गलिय पावावलेव ।
परिभमिरभमररवगुमुगुमन्त, किंकिर णिवसहि णिज्जणवणंत ॥५॥
करि सर वहिरिय दिच्चक्कवाले, पइसरहि ण किं पुरवर विसाले ।
तं सुणेवि भणइ अहिमाणमेरु, वरि खज्जउ गिरिकंदरकसेरु ॥६॥
णउ दुज्जण भंउहा वंकियाइं, दीसंतु कलुसभावंकियाइं ।

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अम्मइय इंदराएहिं तेहिं, आयण्णिय तं पहसिय मुहेहिं ।
गुरुविणयपणाय पणविय सिरेहिं, पडिवयणु दिण्णु णायर णरेहिं ॥१॥

घत्ता ।

जणमणतिमिरोसारण, मयतरुवारण, णियकुल गयण दिवायर ।
भो भो केसवतणुरुह, णवसररुहमुह, कव्वरयणरयणायर ॥२॥
बभंडमंडवारूढकित्ति, अणवरयरइयजिणणाहभत्ति ।
सुहतुंगदेवकमकमलभसलु, णीसेसकलाविण्णाणकुसलु ॥३॥
पाययकइकव्व रसावलुद्ध, संपीय सरासइसुरहिदुद्धु ।
कमलच्छु अमच्छरु सच्चसंधु, रणभरधुरधरणुग्घिट्ठ खंधु ॥४॥
सविलासविलासिणिहिययथेणु, सुपसिद्धमहाकइकामधेणु ।
काणीणदीणपरिपूरियासु, जसपसरपसाहियदसदिसासु ॥५॥
पररमणिपरम्मुहु सुद्धसीलु, उण्णयमइ सुयणुद्धरण लीलु ।
गुरुयणपयपणवियउत्तमंगु, सिरिदेवि अंबगब्भुब्भवंगु ॥६॥
अण्णइयतणउं तणु रुहु पसत्थु, हत्थिव दाणोल्लियदीहहत्थु ।
महमत्तवंसधयवडु गहीरु, लक्खणलक्खंकिय वरसरीरु ॥७॥
दुव्वसण सीहसंघायसरहु, णत्ति याणहि किं णामेण भरहु ।

घत्ता

आउ जाहुं तहो मंदिरु, णयणाणंदिरु, सुकइ कइत्तणु जाणइं ।
सो गुणगणतत्तिल्लउ, तिहुअणिभल्लउ, णिच्छउ पइं सम्माणइं ॥८॥
जो विहिणा णिम्मिउं कव्वपिंडु, तं णिसुणेवि सो संचलिउ खंडु ।
आवंतु दिट्ठु भरहेण केम, वाईसरिसरिकल्लोलु जेम ॥९॥
पुणुतासु तेण विरइउ पहाणु, घरु आयहो अब्भागय विहाणु ।
संभासणु पियवयणेहिं रम्मु, णिम्मुक्कडंभुणं परम धम्मु ॥१०॥

Brahmaṇa of Kāśyapa gotra. His father's name was Keśava and mother's Mughādevī. He was of a tender and ugly constitution[1].

Two other works of Pushpadanta that have come to light are *Yaśodhara charita* and *Nāgakumāra charita.* These are much shorter works than the one mentioned above, containing four and nine *sandhis* respectively. The subject-matter of the former is the same as that of the "*Yaśastilaka Champū* of Somadeva and of the latter the life of a similar other Jaina hero. These two works the author composed at the request of Nanna, the son and successor in office of

तुहुं आयउ णं गुणमणि णिहाणु, तुहुं आयउ णं पंकय हो भाणु ।
पुणु एम भणेप्पिणुमणहराइं, गहणीणरीणतणु सुहयराइं ॥११॥
वरण्हाणविलेवणभूसणाइं, दिण्णाइं देवं गइ णिवसणाइं ।
अच्चंत रसालइं भोयणाइं, गलिआइं जाम कइवय दिणाइं ॥१२॥
देवीसुएण कइ भणिउ ताम, भो पुप्फयंत ससिलिहियणाम ।
णियसिरिविसेसणिज्जियसुरिंदु, गिरिधीरु वीरु भइरवणरिंदु ॥१३॥
पइ मण्णिउ वण्णिउं वीरराउ, उप्पणउं जो मिच्छत्त भाउ ।
पच्छित्तु तासु जइ करहि अज्ज, ताघडइ तुज्झु परलोय कज्जु ॥१४॥
तुहुं देउ कोवि भव्वयण बंधु, पुरुएव चरिय भारस्स खंधु ।
अब्भत्थिओसि देदेहि तेम, णिव्विग्घें लहु णिव्वडइ जेम ॥१५॥

+ + + +

अइ दुग्गमु होइ महापुराणु, कुंडएण मवइं को जलविहाणु ।
अमरासुरगुरुयणमणहरेहिं, जंआसि कयउ मुणिगणहरेहिं ॥१॥
तंहउं कहमि भतीभरेण, किंणहेण भमिज्जइ महुअरेण ।
एहु विणउ पयासिउ सज्जणाहं, मुहे मसि कुच्चउ कउ दुज्जणाहं ॥२॥

[महापुराण-उत्थानिका]

। कसण सरीरें सुद्धकुरूवें, मुद्धाएविगब्भसंभूवें ।
कासवगोत्तें केसव पुत्तें, कइकुलतिलएं सरसइणिलएं ।
उत्तम सत्तें जिणपय भत्तें,.........पुप्फयंत कइणा...

[उत्तरपुराण, संधि १]

Bharata[1]. In the colophons of *Yasodharacharita* the work has been called 'an ornament to the ears of Nanna'[2]. In each of these works the author repeats his parentage. In *Nāgakumāra charita*, however, we find some more information about the author. At more than one place in this work he uses his family designation of 'Bhaṭṭa'[3] with his father's name, and seems to declare that he first belonged to the *Śaiva* faith, but became converted to Jainism by the preaching of a Jaina 'guru'[4].

Pushpadanta was very proud of himself and this is evident even from the epithet *Abhimānameru* that he so frequently uses for himself. The *Tisaṭṭhi salākāpurisa charita* was completed on the 10th of the bright fortnight of *Āshāḍha* in *Krodhana Samvatsara* 887, *Saka* era,

[1] सुहतुंग-भवण-वावारभार-णिव्वहण-वीर-धवलस्स ।
कोंडेल्लगोत्त-नहससहरस्स, पयईए-सोमस्स ॥
कुंदव्वा- गब्भ-समुब्भवस्स, सिरि भरहभट्टतणयस्स ।
जसपसरभरियभुवणायरस्स, जिणचरणकमलभसलस्स ॥
अणवरयरइयवरजिणहरस्स, जिणभवणपूयनिरयस्स ।
कारुण्णकंदणवजलहरस्स, दीणयणसरणस्स ॥
णिवलच्छी कीला सरवरस्स, वाएसरिणिवासस्स ।
णिस्सेसविउस-विज्जाविणोय-णिरयस्स सुद्ध-हिययस्स ॥
णणणस्स पच्छणाए कव्वपिसल्लेण पहसिय मुहेण ।
णाय कुमार चरित्तं रइयं सिरि पुप्फयंतेण ॥

[end of नायकुमारचरित]

[2] इय जसहर-महाराय-चरिए महामहल्लणण्णकण्णाहरणे ।
महाकइ पुप्फयंत विरइये महाकव्वे चउत्थो परिच्छेओ सम्मत्तो ॥

[3] मुद्धाएवी केसव भट्ट पुत्तु । कासवरिसिगोत्ते विसालचित्तु ।

+ + + +

[4] सिवभत्ताइमि जिणसण्णासें । वेविमयाइ दुरियणिण्णासें
बंभणाइ कासव रिसि गोत्तइं । गुरुवयणामयपूरियसोत्तइं ।
मुद्धाएवी केसव णामइं । महु पियराइं होंतु सुहधामइं ।

+ + + +

equivalent to Sunday, the 11th June, 965 A.D.[1] *Nāgakumāra charita* and *Yaśodhara charita* have been composed some time after this date.

In his *Mahāpurāṇa*, Pushpadanta makes mention of *Akalanka, Kapila, Kaṇachara* (kaṇāda), *Purandara, Dantila, Visākha, Luddhāchārya Bharata, Pātañjali, Bhāravi, Bhāsa, Vyāsa, Kohala, Kālidāsa, Chaumukha, Svayambhū, Srī Harsha. Droṇa. Kavi Isāna, Bāṇa, Dhavala* and *Jayadhavala Siddhānta, Rudrata Nyāsakāra, Pingala, Jasa-indhu Śālivāhana, Setubandha kārya* (of Pravarasena) *Jinasena* and *Vīrasena.*[2]

[1] The date of the author has been fully discussed by the writer in a Hindi article shortly to appear in the pages of 'Jain Sāhitya Samśodhaka, and in the introduction to the 'Catalogue of Sanskrit and Prākrit MSS. in the Central Provinces and Berar' prepared by Rai Bahadur Hira Lal, B. A., M. R. A. S. (Retd. deputy commissioner). The latter work is in the Govt. Press, Nagpur, for publication. The passage chiefly bearing on the date is to be found at the end of '*Uttarapurāṇa.* It reads thus :—

पुप्फयंतकयणा धुयपंकें जइ अहिमाण मेरुणामंकें
कयउ कव्वु भत्तिएं परमत्थें, छसय छडोत्तर कय सामत्थें
कोहण संवच्छरे आसाढए, दहमए दियहे चंदरुइरूढए ।

In the Kāranjā MS. of the work, however, the second foot of the second line reads :—

'जिणपयपंकयमौलियहत्थें' ।

अकलंक-कविल-कणयर-मयाइं, दियसुगय पुरंदर णय सयाइं ।
दन्तिल-विसाहि-लुद्धारियाइं, णउ णायइं भरह वियारियाइं ॥
णउ पीयइ पायंजलि-जलाइं, अइहास पुराणइं णिम्मलाइं ।
भावाहिउ भारवि भासु वासु, कोहलु कोमलगिरु कालिदासु ॥
चउमुहुं सयंभु सिरि हरिसु दोणु, णालोइउ कइ ईसाणु बाणु ।
णउ वुज्झिउ आयम सद्दधामु सिद्धंतु धवलु जयधवलु णामु ।
पडु रुद्दडु जडणि णासयारु, परियच्छिउ णालंकार सारु ॥
पिंगल पत्थारुसमुद्दे पडिउ, ण कयाइ महारइ चित्ते चडिउ ।
जसइंधु सिंधु कल्लोल सित्तु, ण कलाकोसले हियवउ णिहित्तु ॥
राउ सालिवाहणु वि विसेसिउ, पइं णियजसु भुवणयले पयासिउ ।
जो बाल-वुड्ढ-संतोसहेउ, रामाहिरामु लक्खणसमेउ ।
जो सुम्मइं कइ वइ विहिय सेउ, तासु वि दुज्जणु किं परे महोउ ॥
जिणसेणेण वीरसेणेणवि, जिणसासणु सेविउ मयगिरि पवि ।

§6. '*Harivaṁśapurāṇa*' of 'Dhavala' is another large work in Apabhraṁśa. It is completed in 122 *sandhis* equalling 18000 ślokas[1]. The poet was the pupil of Ambasena Ṛishi, and the son of a Brahmaṇa by name 'Sūra'[2]. The author's name appears in the last verse of each *sandhi* as well as in the preface to the work, where we also find mention of the following authors and their works[3]:—

Dhīrasena.

Samattajutta (author of a work on Pramāṇa.)

[1]The work begins thus:—

लोयालोयदीहणालं गोमिहणीकण्हकेसरसुसोहं ।
महपुरिसतिसट्ठिदलं हरिवंससरोरुहं जयऊ ॥ १ ॥
हरिपंडुवाणकहा चउमुह वासेहि भासियं जइया ।
तह विरयमि लोयपिया, जेण ण णासेइ दंसणं पउरं ॥ २ ॥

* * *

जइगोत्तमेण भणियं सेणिय रायेण पुच्छियं जइया ।
जह जिणसेणेण कयं तह विरयमि किंपि उद्देसं ॥ ४ ॥

* * *

सुव्वउ भवियाणंदं, पिसुणचउक्कायभव्वजणसूलं ।
धणणुय धवलेण कयं हरिवंस ससोहणं कव्वं ॥ ८ ॥

* * *

जिणणाहहोकुसुमअलिदेविणु । णिब्भूसणमुणिवरपणवेप्पिणु
पवरचरियहरिवंसकवित्तें । अप्पउ पयडिउ सूरहो पुत्तें ।
[2]मयि विप्पहो सूरहोणंदणेण, केसुल्लउअरितह संभवेण ।
जिणवरहो चरण अणुरत्तएण, णिग्गंथह रिसियहु भत्तएण ।
कुतित्थ कुधम्म विरत्तएण, णामुज्जलु पयडु वहंतएण ।
हरिवंस सुयलु सुललिय पएहि, मइविरइउ सुट्ठुसुहावएहि
सिरि अंबसेण गुरुवेण जेम, वक्खाणिकियउ अणुकमेण तेण
[3]जो णवि मरइ ण सिज्झइ, णवि पीडिज्जइ अक्खउ भुवणि अभीउ ।
करमि सुयण संभावउ, खल संतावउ हउ कव्वमउ सरीरु ॥ २ ॥
कवि चक्कवइ पुव्व गुण वंतउ । धीरसेणु होंतउ सुपसिद्धउ ।
पुणु समत्तजुत्तु सरागउं । जेण पमाण गंथ किउ चंगउ ॥ १ ॥

Devanandi (author of Jainendra Vyākaraṇa.)
Bajrasūri (author of a work on Naya.)
Mahāsena (author of Sulochanā Charita.)
Ravisheṇa (author of Padma Charita.)
Jinasena (author of Harivamśa Purāṇa.)
Jaḍilamuni (author of Varāṅga Charita.)
Dinakarasena (author of Anaṅga Charita.)
Padmasena.
Andhasena (author of Amiyārāhanā.)
Dhanadatta (author of Chandraprabha Charita.)
Vindhyasena (author of many Charitas.)
Simhanandi (author of 'Anupreksha'.)

देवणंदि बहुगुण जस भूसिउ । जे वायरणु जिणेंदु पयासिउ ।
वज्जसूउ सुपसिद्धउ मुणिवरु । जे णय माणु गंथु किउ सुंदरु ॥ २ ॥
मुणि महसेणु सुलोयणु जेण । पउम चरिउ मुणि रविसेणेण ॥ ३ ॥
जिणसेणेण हरिवंसु पवित्तु । जडिल मुणीण वरंग चरित्तु ।
दिणयर सेणे चरिउ अणंगहो । पउमसेण आइरियहु पासहो ॥ ४ ॥
अंधसेणु जे अमियाराहणु । विरइय दोस विवज्जिय सोहणु ।
जिणचन्दप्पह चरिउ मणोहरु । पाव रहिउ धणयत्तु सुसुंदरु ॥ ५ ॥
अण्णामि किय पमाइ बहुत्तइं । विण्हसेण रिसपुण चरित्तइ ।
सीहणंदि गुरवे अणुवेहा । णरदेवेंण वयारसु णेहा ॥ ६ ॥
सिद्धसेणु जे गेए आगउ । भविय विणोय पयासिउ चंगउ ।
रामणंदि जे विविहपहाड़ा । जिणसासणि बहु रइय कहाणा ॥ ७ ॥
असगु महाकइ जेंसु मणोहरु । वीरजिणेंदचरिउ किउ सुंदरु ।
केत्तिय कहमि सुकइ गुण आयर । गेय कव्व जहिं विरइय सुंदर ।
सणकुमारु जे विरयउ मणहरु । कय गोविंद पवरु सेयं वरु ॥ ८ ॥
तहं वर कइ जिणरक्खिय सावउ । जे जयधवलु भुवणि विक्खायउ ।
सालिभद्द कय जीय उद्देदउं । लोए चउमुह दोण पसिद्धउं ।
एकहि जिणसासणे उच्छलियउ । सेदु महाकइ जसु णिम्मलियउ ।
पउमचरिउ जिं भुवणि पयासिउ । साहुराहियार वरहिं पसंसिउ ।
हउ जडु तोवि किं पि अत्तासमि । महियलेजि णियबुद्धि पयासमि ।

घत्ता

सहसकिरणु रइ वेवि, गयणि चडेवि, तिमिरु असेसु पणासहिं ।
णिय सत्तें मणि दीवउ, जइ विसुयोवउ, ते विउ जोवि पयासहिं ॥

Siddhasena (sang the Āgama and manifested 'Bhaviya Vinoda'.)
Rāmanandi (author of many stories.)
Asaga (author of Vîra Charita.)
Govinda (author of 'Sanatkumāra Charita'.)
Jinarakshita (author of 'Jayadhavala'.)
Śālibhadra (author of 'Jîva Udyota'.)
Chaumuha (author of Paumacharia.)
Droṇa.

Nothing is so far known about many of the authors and their works referred to here. All those, whose works have come to light, are known to have lived in or prior to the 10th century A.D. Among these the latest in date is *Asaga*, the author of Vîra Charita (Varddhamāna Kāvya), from some MSS. of which, Asaga is known to have been writing in the year 910[1]. If we refer this date to the Vikrama era we get the year 853 A.D. or if to the Śaka era, the year 988 A.D. for Asaga. Dhavala must have been writing shortly after one of these dates. But in that case it is strange that Dhavala omitted to mention Jinasena, the famous author of Ādipurāṇa, whom Pushpadanta refers to. Dhavala does not mention Pushpadanta nor the latter the former, though

[1]The praśasti appended to some MSS. of Varddhamāna Kāvya and furnishing the above date for *Asaga*, is the following :—

संवत्सरे दशनवोत्तरवर्षयुक्ते
भावादिकीर्त्तिमुनिनायकपादमूले
मौद्गल्यपर्वतनिवासधनस्य संपत्
सच्छ्राविका प्रजनिते सति वा ममत्वे ॥१॥
विद्या मया प्रपठिते त्यसगाह्वयेन
श्रीनाथराज्यमखिलं जनतोपकारि
प्रापे च चौडविषये वरलानगर्यां
ग्रंथाष्टकं च समकारि जिनोपदिष्टम् ॥२॥

both were poets of no small magnitude. It is likely, therefore, that they were near contemporaries.

§7. Two large works of Apabhramśa have recently been discovered. They are *Harivamsapurāṇa* and *Paumacharia.*[1] They are roughly equivalent to 18,000 and 12,000 ślokas respectively.[2] The author of both these works is Svayambhūdeva. He, however, left both the works incomplete, and they were finished by his son Tribhuvana Svayambhū. In Harivamśapurāṇa, Svayambhūdeva calls himself a protège of one '*Dhavalaiyā*', while in 'Paumacharia,' he calls himself a protège of '*Dhanañjaya.*' Probably these two names refer to one and the same person.[3] Tribhuvana Svayambhū calls himself the protège of 'Bandaiyā' who may have been the son of 'Dhavalaiyā.' From the sandhis towards the end of Harivamśapurāṇa, we learn that a portion of the work written by Tribhuvana Svayambhū was lost and that it was subsequently restored by Jasakitti (Yasah kîrtti) Bhaṭṭāraka of Gwalior.

[1]Pandit Nāthūrām Premi is the first to announce their discovery. To him I am indebted for all my information about the works and their author.

[2]The Mañgalācharaṇa of Harivamśa Purāṇa is :—

सिरि परमागमणालु सयलकलाकोमलदलु ।
करहु विहूसणु कण्णे जायव कुरुव कुहुप्पलु ॥ १ ॥
पणमामि णेमि तित्थंकरहो । हरिबलकुलनहयलससहरहो ।
तइलोक्कलच्छिलच्छियउरहो । परिपालयअजरामरपुरहो ॥ २ ॥

The Mañgalācharaṇa of Paumacharia is :—

महणव-कोमल-कोमल-मणहर-वर-वहल-कंति-सोहिल्लं ।
उसहस्सपाय कमलं ससुरासुरवंदियं सिरसा ॥ १ ॥

[3]चिंतवइ सयम्भु काइ करम्मि । हरिवंसमहण्णव के तरम्मि ।
गुरुवयणतरंडउ लध्दुनवि । जम्महो विणजोइउ कोवि कवि ॥

Each *Sandhi* of Harivamśapurāṇa up to the 98th *sandhi* ends, *mutatis mutandis*, with the following verse :—

इयरिट्ठणेमि चरिए धवलइयासिय सयंभुएव कये
पढमो समुद्दविजयाहिसेयणामो इमो सग्गो ॥

In the Harivamśapurāṇa, we find mention of *Bhāmaha*, *Daṇḍin*, *Bāṇa*, *Hārisheṇa* and *Chaumuha*; and in the Paumacharia, that of *Ravisheṇa*, *Bhāmaha* and *Daṇḍin*. None of these are known to have lived after the 7th century A.D. Of Svambhūdeva himself, mention is found in the epic of Pushpadanta. From these facts it may be concluded that Svayambhūdeva wrote some time between the 7th and the 10th century A.D.

§8. '*Kathā kosha*' of Śrīchandra-muni is another work now brought to notice for the first time. The work is completed in fifty-three *sandhis* and contains about an equal number of stories meant for moral and religious instruction.[1]

In *Sandhis* after the 98th we have:—

इयरिट्ठणेमि चरिए धवलइया सिय सयंभुएव उच्चरिये ।
तिहुयण सयंभुरइए सग तणेयं सोय बलहद्दं ॥ १०७ ॥

Similarly, in Paumacharia, first *sarga*, we have:—

इय एत्थ पउमचरिए धणंजयासिय सयंभुएव कए ।
जिणजम्मुप्पत्ति इयं, पढमंचिय साहियं पव्वं ॥ १ ॥

In the rest of the *sargas* we have:—

इय पउमचरियसेसे, सयंभुएवस्स कहवि उच्चरिए ।
तिहुअण सयंभु रइयं, समाणियंसीयदीव पव्वमिणं ॥

That Tribhuvana Svayambhû was the son of Svayambhû deva, is proved by the following verse of Harivamśapurāṇa:—

एक्को सयंभुविउसो तहोपुत्तो णाम तिहुवण सयंभो ।
को वण्णिउं समत्थो पिउभरणिव्वूढणएक्कमणो ॥

[1] The work opens thus:—

ॐ नम पणवेवि, चित्ते थवेवि, नट्ठट्ठादसदोसु ।
लोयत्तय-वंदु, देउ जिणेंदु, अक्खासमि कइकोसु ॥
पणवेप्पिणु जिणु सुविसुद्धमई । चिंतई मणि मुणि सिरिचंदु कई ।
संसारु असारु सव्वु अथिरु । पिय-पुत्त-मित्त माया तिमिरु ॥
संपय पुणु संपहें अणुहरइ । खणि दीसइ खणि पुणु उसरइ ।
सुविणय समुपेम्मु विलासविही । देहुवि खणिभंगु गुरु दुक्ख तिही ॥
जोव्वणु गिरि वाहिणि वेय गउ । लायण्णु वण्णुकर सलिल सउ ।
जीविउ जल-बुब्बुय-फेण-णिहु । हरि जालु वरज्जु अवउज णिहु ॥

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Verses, in metres different from the prevailing one, occur in the body of the work.[1] The name of the author occurs in the last verse of each *sandhi*.[2] A *praśasti* in Sanskrit is appended to the work by which we learn that the author was the disciple of Vīra Chandra, the disciple of Guṇākarakîrtti, the disciple of Śrutakîrtti, the disciple of Śrîkîrtti of the Kundakunda line of Āchāryas, and that he composed the work for the family of Kṛishṇa, the son of Sajjana of Prāgvāṭa family and a resident of Aṇhillapura, and the councillor (*Goshṭika*) of king Mûlarāja. History tells us that there have been two kings of this name in the Chālukya line of Aṇhillvāḍ. The first was the founder of the dynasty and reigned from A.D. 941 to 996, and the second, who was the tenth in the line, sat on the throne in 1176 A.D. and

[1] 'लहेवि सिद्धिं च समाहि कारणं'
समत्थसंसार दुहोह वारणं ।
पहुं जए जं सरसं निरन्तरं ॥
सुहं सयातप्फलजं अणुत्तरं ।
[वंसस्थ छंद]

\+ + +

तेणाणु माउ । वड्ढिउ पमाउ ।
सम्मत्त णाण । तव चरण थाण ॥
सेणाइ मोह । मिछत्त जोह ।
इंदिय कसाय । परिसह विसाय ॥
उव सग्ग आइ । निद्धिवि अराइ ।
पावेवि मोक्ख । सिरि पहय दुक्ख ॥
[दुहखहउ नाम छंदः]

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[2] The following verse is repeated with slight variations at the end of each *Sandhi*.

मुणि सिरि चंद पउत्ते कहकोसे पत्थ जणमणाणंदे ।
पन्नासमउ संधीए सोएगू णाउ भणिउ ॥

ruled only for two years.[1] Our author flourished about the time of one of these kings, probably of the first.

§9. *Pārśvapurāṇa* of Padmakîrtti consists of eighteen *sandhis,* and is equal to 3,323 ślokas. It narrates the life of Pārśva-nātha the twenty-third Tīrthamkara of the Jainas. From the *Praśasti* appended to the work, it is known that the author was the pupil of Jinasena, the pupil of Mādhavasena, the pupil of Chandra sena[2]. Nothing can be said about the date of the author. But, the MS. of the work that I saw in Kāranjā Bhāndār is dated in *Samvat* 1473, *Phalguṇa Vadi* 9, Wednesday when Vīrabhānadeva was ruling.

§10. *Sudarśana Charita* of Nayanandi is a work in twelve *sandhis.* It narrates the life of a religious hero, Sudarśana.[3] From the *Praśasti* appended to the work

The foregoing verse is always preceded by the one following :—

विविह-रस-विसाले णेय कोऊ हलाले ।
ललिय-वयण-माले, अत्थ-संदोह-साले ॥
भुवण-विदिद-णामे, सव्व-दोसोवसामे ।
इह खलु कह कोसे, सुन्दरे दिण्ण तोसे ॥

[1] Ind. Ant., Vol, VI. p. 213.

[2] सुपसिद्ध महामहुणियम धरु । थिउ सवण संघु इह महिहिघरु ।
तहि चंदसेणु णामेणरिसि । वय-संजम-नियमइ जासुकिसि ॥
तहु सीसु महामइ नियम धारि । णयवंतु गुणायउ वंभयारि ।
सिरि माहवसेणु महाणु भाउ । जिणसेणु सीसु पुणु तासु जाउ ॥
तहो पुव्व सणेहं पउम किित्ति । उप्पणु सीसु जिणुसासु चित्ति ।
तेजिणवर सासणे भत्रिय एण । कहा विरइय जिणसेणहो मएण ॥
गारवमयदोसविवज्जिएण । अक्खर पय जोडिय लंज्जिएण ।
कुकइति यि जणे सुकइत्तुहोइ । जइ सुवणह भावइंदत्थ लोइ ॥
जइ अम्हिवि चोक्के वि किंपिपुत्तु । खमिएव्वउ सुयणहि तं णिउत्तु ।
रित्तसि गुरु देवं पसाए । कहिउं असेसु ति दरिउ मइ ।
पउम किित्त मुणि पुंग वहो । दिउ जिणेसरु विमल मइ '

[3] The work begins thus :—

ऊंनमः सिद्धेभ्यः । णमो अरहंताणं । णमो सिद्धाणं, णमो आइरियाणं । णमो उवज्झायाणं । णमोसलएवसाहूणं ।

we learn that the author was the pupil of *Māṇikya-nandi*, pupil of *Rāmanandi*, pupil of *Viśākhanandi*, pupil of *Padmanandi* of the Kundakunda line of Āchāryas, and that he wrote his work in *Vikrama Samvat* 1100, when king Bhojadeva was reigning at Dhārā in Avantideśa.[1] This same Nayanandi may be the author of 'Ārādhanā' mentioned in the introduction to Bhavisayattakahā (G. O. S.) on p. 42.

§11. *Karakaṇḍū Charita* of Kanakāmara is in ten chapters, here called *parichchhedas*.[2] It narrates the life of a king and sage Karakaṇḍū. The author makes mention

इह पंच णमोक्कारहं लहेवि गोवहुवउ सुदंसणु ।
गउ मोक्खहो अक्खमितहो चरिउ व चउवग्गपयासणु ॥

[1] जिणंदस्स वीरस्स तित्थे महंते । महाकुंदकुंदन्वए एंत संते ।
सुणरकाहिहाणो तहा पोमणंदी । खमाजुत्त सिद्धंतउ विसहणंदी ॥
जिणिंदागमाहासणो एयचित्तो । तवारणद्धीए लद्धीए जुत्तो ।
णरिंदामरिंदेहिं सोणंदवंती । हुउ तस्स सीसो गणी रामनंदी ॥
महापंडऊ तस्स माणिक्कणंदी । भुयंगप्पहाऊ इमोणामछंदी ।

घत्ता

पढम सीसु तहो जायउ, जगविक्खायउ, मुणि णयणंदि अणिंदिउ ।
चरिउ सुदंसण णाह हो, तेण अवाहहो, विरइउ बुह अहिणंदिउ ॥
आरामगाम पुर वरणिवेसे । सुपसिद्ध अवंती णाम देसे ।
सुरवइ पुरिव्व विवुहयणइट्ठ । तहिं अत्थि धारणयरी गरिट्ठ ॥
रणउद्धर अरिवरसेलवज्ज । रिद्धिं देवासुर जणि चउज्ज (?)
तिहुवण णारायण सिरिणिकेउ । तहिंणरवर पुंगमु भोयदेउ ।
मणिगण पह दूसियरविगभत्थि । तहिं जिणहरु पडुविवहारु अत्थि ।
णिवविक्कम कालहो ववगएसु एयारहसंवच्छर सएसु ॥
तहि केवलि चरिउ अमच्छरेण । णयणंदियविरइउ वच्छरेण ।
जोपढइ सुणइ भावइ लिहेइ । सोसासय सुहु अइरेंलहेइ ॥

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[2] The work begins thus :—
मणमारविणासहो, सिवपुरवासहो, पावतिमिरहरदिणयरहो ।
परमप्पयलीणहो, विलयविहीणहो, सरमि चरणु सिरिजिणवरहो ॥

of *Siddhasena*, *Samantabhadra*, *Akalankadeva*. *Svayambhū* and *Pushpadanta*.[1] He must, therefore, have been writing some time in or after the 10th century A.D.

§12. '*Mehesara charia*' of Simhasena is yet another work, that has of late come to light. It has also been called '*Ādipurāṇa*'.[2] The author wrote it for Khema Simgha or Khemarāja, whose name appears in the colophon of each *Sandhi*.[3] The poet was also known by the name of '*Raidhu*.' He was the son of Harasimgh Simghai and the pupil *Yasahkīrtti*, pupil of *Guṇakīrtti*.[4] These

जय अणुवमसिवसुहकरणदेव । देवेंदफणिंदणरिंदसेव ।
जय णाणमहोदहिकखियपार । पाराविय सिवपहे भवियतार ॥

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The colophon at the end is:—

इय करकण्डुमहारायचरिए मुणिकणयामरविरइए भव्वयणकण्णावयंसे पञ्च कल्लाणविहाणकप्पतरुफलसंपत्ते करकंडुसव्वच्छसिद्धिलाहो णाम दहमो परिच्छेउ सम्मत्तो ॥

[1] जइ कवियण सेव हो मइणकीय । जइ जडयण संगइ मलिणकीय ।
तो सिद्धसेण सुसमन्त भद्द । अकलंक देव सुअजल समुद्द ।
जय एव सयंभु विसाल चित्त । वाएसरि घरु सिरि पुप्फयंतु ।

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[2] णिसुणहु अणुराए रसभरिओ । सिरिमेहेसर गणहर चरिओ ।
इयसंणियरायहु, कयअणुरायहु, गोयमेण जसविप्फुरिओ ।
मेहेसरचरिओ बहुगुणभरिओ, अक्खिउ बुहयणआयरिओ ।

[3] महाभव्व-खेमसी-साहु-णामंकिए...

[4] णंदउसिरि हरसिंघ संघाहिउ । देवराज सुउ पवर गुणाहिउ ।
जस संताणि कईसु अमच्छरु । रइधू संजायउ गुणकोच्छरु ।
जेण चरिउ उसहेण हु केरउ । विरयउ बुहयणसुक्ख जणेरउ ।

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णं सरसइसुरसरियणायरु । सत्थअत्थसुपरिक्खणणायरु
सिरि गुणकित्ति णामु जइ पुंगमु । तउ तवेइ जो दुविहअसंगमु ।
पुणु तहु पदिय वरजस भायणु । सिरिजसकित्ति भव्वसुहदायणु
तहुपयपंकयाइं पणमंतउ । जावुहणिवसइ जिणपयभत्तउ ।

Āchāryas are known to have lived about the time of king Kīrttisimgha of Tomara family who was reigning at Gwalior in A.D. 1464.[1] Thus Simhasena alias Raidhu must have been writing about this time. Simhasena has mentioned in his work, *Guṇākara, Dhīrasena, Devanandi, Jinavarasena, Ravisheṇa, Jinasena, Surasena, Dinakarasena, Svayambhū, Chaumuha* and *Pupphayanta.*[2]

'Raidhû is also the author of another small work *Dahalakkhaṇujayamāla*' (Daśalākshaṇika jayamāla). It contains in all sixty-eight Apabhramśa verses, six or seven on each of the ten articles of dharma of the Jainas.[3] The name of the author appears in one of the concluding verses.

ता रिसिणा सो भणिउ विणोए । इत्थुणिएवि सुमुहुत्ते जोए ।
भो सिंघिय सेणय सुसहाए । होसिवियक्खणु मज्झ पसाए ।
इयभणेवि मंतक्खरदिण्णउ । तेण रहिउ तंजि अच्छिण्णउ ।
चिर पुण्णे कइत्त गुणसिद्धउ । सुगुरु पसाए हुवउ पसिद्धउ ।

[1] In a Praśasti appended to the MS. of 'Jnānārṇava' deposited in the Jaina Siddhānta Bhavana, Arrah, we read :—

संवत् १५२१ वर्षे आषाढ़ सुदी ६ सोमवासरे श्रीगोपाचलदुर्गे तोमरवंशे राजाधिराजश्रीकीर्त्तिसिंह-राज्यप्रवर्तमाने श्रीकाष्ठासंघे माथुरान्वये, पुष्करगणे भ० श्री गुणकीर्त्तिदेवास्तत्पट्टे भ० श्री यशःकीर्त्ति देवास्तत्पट्टे भ० श्रीमलयकीर्त्तिदेवास्तत्पट्टे भ० श्रीगुणभद्रदेवास्तदाम्नाये ....

[2] वाएसरि-सुरसरि - रयणायर । हुअ पुणु आसि कइंद गुणाकर ।
सुअ वयणा दाविय मिच्छारय । धीरसेणु कइ चक्कि विहियदय ॥१॥
देवणंदि गणि विज्जामंदरु । जेण विहिउ वायरणु महाचिरु ।
छद्दंसणपमाणु पविसेसें । विरयउ पालिय जिणवयसेणें ॥२॥
मेहेसर चरिओ सुरसेणें । चरिउ अणंगहो दिणयर सेनें ।
पुणुवि सयंभु महाकइ जायउ । चउमुह पुप्फयंत विक्खायउ ॥३॥
इयवर विज्जहि वरकइ जाया । तिह कारणि महु फुरइण वाया ।

[3] The ten dharmas are enumerated in the first verse of the work :—

उत्तम खम मद्दउ, अज्जउ सच्चउ पुण सउच्च संजम सुतओ ।
चाउ वि आकिंचणु, भव-भय-वंचणु, बंभच्चेरु धम्मजु अक्खओ ।
उत्तम खम तिल्लोयहसारी । उत्तम खम जम्मोदहितारी ।
उत्तम खम रयणत्तय धारी । उत्तम खम दुग्गइ दुह हारी ।
+ + + +

These two works of Raidhû prove that the Apabhraṁśa language continued to be the vehicle of literature among the Digambara Jainas as late as the 15th century A.D.[1].

The ending verses of the work are :—

बाहिर फासेंदिय सुह रक्खहु । परम बंभु अब्भंतर पिक्खहु ।
एण उवाए लब्भइ सिवहरु । इम रइधू बहु भणइ विणय यरु ॥
जिणणाह महिज्जइ, मुणि पणमिज्जइ, दह लक्खणु पालियइ णिरु ।
भो खेमसींहसुय भव्व विणयजुय, होलु व मण इह करहु थिरु ॥
इय काऊण णिज्जरं । जे हणंति भव पिंजरं ।
नीरोयं अजरामरं । ते लहंति सुक्खं परं ॥१॥
जेण मोक्खु फलु तंपाविज्जइ । सो धम्मंगो एहहु किज्जइ ।
खम खम्मायलु तुंगय देहउ । मद्दउ पल्लउ अज्जउ साहउ ॥
सच्च सउच्च मूल संजम दलु । दुविह महातव णव कुसुमाउलु ।
चउ विह चाउ पसारिय परमलु । पीणिय भव्वलोय छप्पइ यलु ॥
दिय संदोह सह कल कलयलु । सुरणर वर खेयर सुह सयफलु ।
दीणा णाह दीह समणिग्गहु । सुद्ध सोम तणु मत्त परिग्गहु ॥
बंभचेरु छायाइ सुहासिउ । रायहंस नियरेहि सभासिउ ।
एहउ धम्म-रुक्ख लाखिज्जइ । जीव दया वयणहि राखिज्जइ ॥
झाणठाण भल्लारउ किज्जइ । मिच्छा मयउ पवेस णदिज्जइ ।
सीलसलिल धारहि सिंचिज्जइ । एम पयत्ते वड्ढारिज्जइ ॥

घत्ता

कोहानल चुक्कउ, होउ गुरुक्कउ, जाइ रिसिंदिय सिट्ठ गई ।
जगताइ सुहंकरु, धम्म महातरु, देइ फलाइ सुमिट्ठ मई ॥

[1] My information about this author and his two works is based upon the दशलाक्षणिकधर्मजयमाला, published by the 'Jaina Granth Ratnākara Kāryālaya,' Bombay, 1923, and upon an article of Babu Jugal Kishore Mukhtar, published in the Hindi monthly 'Jaina Hiteshi' Vol. 13, pp. 103-107.

§13. *Yogasāra* or *Dohāsāra* of Yogachandra Muni contains 107 Apabhramśa verses. The metre of the work is '*dohā*', which alternates at one or two places only with a verse in *Sorațhā* or *Chaupai*[1]. Its language comes so near the modern vernaculars that we may call it old Hindi. It thus illustrates the last stage of the Apabhramśa language. This author may be identical with the author of Paramātmaprakāśa (cf., p. 160 footnote). Pt. Nāthûrāma Premi assigns the poet to the 12th century A.D. The subject-matter of the work is spiritual didacticism.[2]

§14. A work, similar to the Yogasāra of Yogachandra, has recently been discovered by the writer. It is the

[1]The work begins with the verse

णिम्मलझाण परट्ठिआ कम्मकलंक डहेवि ।
अप्पा लद्धउ जेण परु ते परमप्प णवेवि ।। १ ।।

\+ + +

अप्पसरूवह जो रमइ छंडवि सव ववहारु ।
सो सम्माइट्ठी हवइ लहु पावइ भवपारु ।।

\+ + +

धम्मुण पढिया होइ धम्मुण पोच्छापुच्छयइ ।
धम्मुण मढिय पयेसि, धम्मुण मुच्छालुञ्चयइ ।

× + +

जीवा जीवह भेउ, जो जाणइ सो जाणियउ ।
मोक्खह कारण एउ, भणइ जोइ जोइहि भणिउ ।।

\+ + +

कासु समाहि करउ को अंचउ । छोपु अछोपु करिवि को वंचउ ।
हल सह कलहि केण सम्माणउ । जहिं जहिं जोवउ तहं अप्पाणउ ।।

\+ + + +

संसारह भय भीय एण । जोगचंद मुणिणा ।
अप्पसंबोहण कया । दोहा इक मणेण ।।

[2]This work has recently been published in Maņika chandra Digambara Jaina Granthamālā No. 21.

Srāvakāchāra of Dewasena.[1] It deals with the conduct of Jaina laity in about 250 *dohā* verses. The name of the author occurs in the last verse which is somewhat faulty in the MS.[2]

Five Prākṛit works of Dewasena have already been published. According to a statement in one of these works, *Darśanasāra*, Dewasena wrote in *V. S.* 990[3]. Considering the language of the *Śrāvakāchāra*, we would not be justified in identifying its author with the author of 'Darśana sāra', and thus assign the work to as early a period as the 10th century A.D. There is, however, a circumstance, which induces me to think that the 'Śrāvakāchāra' may be originally the work of the same Dewasena. The concluding verses of *Nayachakra*, one of the works of Dewasena, tell us that the work was originally composed by the author in 'Dohās', when, however, it was recited to one Subhaṁkara, the latter observed with a smile that the metre did not befit the subject-matter of the

[1] The work begins thus :—

णाम कारेपिणु पंच गुरु, दूरि दलिय-दुहकम्मु ।
संखेवे पयडक्खरहि, अक्खमि सावय धम्मु ॥१॥
दुज्जणु सुहियउ होउ जाग, सुयणु पयासिउ जेण ।
अमियउ विसु वासर जमह, जिम मर गउ कच्चेण ॥२॥
जिह समिला सायर गयहि, दुल्लहु जुब्वहरंतु ।
तिह जीवह भव जलगयह, मणु वत्तणु संबंधु ॥३॥

\+ \+ \+

एहु धम्मु जो आयरइ चउवण्णाह मह कोइ ।
सो णरु णारी भव्वयणु सुरइय पावइ सोइ ॥

× × ×

[2] इय दोहा वड्ढवय धम्म देवसेने उवदिट्ठ ।
लहु अक्खर मत्ता हीयमो पय सयणा खमंतु (?)

[3] रइओ दंसण सारो हारो भव्वाण णवसए णवए ।
सिरि पास णाह गेहे सुविसुद्धे माह सुद्ध दसमीए ॥२०॥

[दर्शनसार]

work which might be better turned into '*gāthā* verses'. This was subsequently accomplished by a pupil of Dewasena, by name 'Māilla dhavala.'[1] This clearly shows that Dewasena used to write in *dohā* metre. Probably the use of this metre was new at that time and hence it did not appeal to the said 'Subhamkara.' May be, that the Śrāvakāchāra is a work of this very author, but in that case it must be admitted that the language of the work has been tampered with.

§15. *Jayatihuyaṇa stotra* of *Abhayadeva sūri*, in point of language, belongs to the same category as the above two works. It consists of thirty verses only.[2]

§16. There occur forty verses in the daily ritual of the Digambara Jainas, which are purely Apabhramśa. Eight of these form the '*Deva Jayamāla*', thirteen the '*Śāstra Jayamāla*', another thirteen the '*Guru Jayamāla*' and the remaining six the '*Pañchaparameṣṭhī*

[1] सुणिऊण दोहरत्थं सिग्घं हसिऊण सुहंकरो भणइ ।
एत्थ ण सोहइ अत्थो गाहाबंधेण तं भणह ॥
दव्व सहाव पयासं दोहयबंधेण आसिजं दिट्ठं ।
तं गाहा बंधेण रइयं माइल्ल धवलेण ॥

[2] This work has been noticed by Peterson in his Report. III. p. on p 245.

जय तिहुयण वर कप्प रुक्ख जय जिणधन्नंतरि
जय तिहुयण कल्लाण कोस दुरियक्खरि केसरि ।
तिहुयण जण अविलंघि आण भुवणत्तय सामिय
कुणसु सुहाइ जिणेस पास थंभणयपुरिट्ठिय ॥ ३ ॥

× × × ×

एय महारिय जत्तदेव इहुन्हवण महूसऊ
जं अणलिय गुण गहणु तुम्हं मुणिजण अणिसिद्धउ ।
एम पसीय सुपास णाह थंभणय पुरट्ठिय,
इय मुणिवरु सिरि अभयदेउ विण्णवइ अणिंदिय ॥२०॥

Jayamāla'.[1] Of these, the first has been appropriated from the Yaśodharacharita of '*Pushpadanta.*' Very likely the rest

[1] 'देवजयमाल'

वत्ताणुट्ठाणे, जणधणुदाणे, पइपोसिउ तुहु खत्तधरु ।
तुहु चरण विहाणे, केवल णाणे, तुहु परमप्पउ परमपरु ॥ १ ॥
जय रिसहरिसीसर णमिय पाय । जय अजिय जियंगमरोसराय ।
जय संभव संभव कयविओय । जय अहिणंदण णंदिय पओय ॥ २ ॥

× × × ×

जय पास पास छिंदण किवाण । जय वड्ढमाण जस वड्ढमाण ॥ ७ ॥

घत्ता

इह जाणिय णामहिं, दुरिय विरामहिं, परहिं वि णमिय सुरावलिहिं ।
अणहणहिं अणाइहिं, समिय कुवाइहिं, पणमिवि अरहंतावलिहिं ॥ ८ ॥

× × × ×

शास्त्रजयमाल—

संपइ सुह कारण, कम्म वियारण, भवसमुद्दतारणतरणं ।
जिणवाणिणमस्समि, सत्तपयास्समि, सग्गमोक्खसंगमकरणं ॥ १ ॥
जिणिंद मुहाउ विणिग्गयतार । गणिंद विगुंफिय गंथ पयार ।
तिलोयहिमंडण धम्मह खाणि । सयापणमामि जिणिंदह वाणि ॥ २ ॥

\+ + + +

इह जिणवर वाणिविसुद्ध मई । जो भवियण णिय मण धरई ।
सो सुर णरिंद संपय लहइ । केवल णाण विउत्तरई ॥ १३ ॥

× × × ×

गुरुजयमाल

भवियह भवतारण, सोलह कारण, अज्जवि तित्थयरत्तणहं ।
तव कम्म असंगइ, दय धम्मंगइ, पालवि पंच महाव्वयहं ॥ १ ॥
वंदामि महारिसि सीलवंत । पंचिंदियसंजमजोगजुत्त ।

× × × ×

जे तप सूरा, संजमधीरा, सिद्धवधूअणुराईया ।
रयणत्तयरंजिय, कम्मह गंजिय, ते रिसिवर मउ झाईया ॥ १३ ॥

पञ्चपरमेष्ठिजयमाल

मणुय णाइन्द-सुर-धरिय छत्तया । पञ्च कल्लाण सुक्खावली पत्तया ।
दंसणं णाण झाणं अणंतं बलं । ते जिणा दिंतु अम्हं वरं मंगलं ॥ १ ॥

× × × ×

एण थोत्तेण जो पंच गुरु वंदये । गुरुय संसर घण वेल्लि सो छिंदये ।
लहइ सो सिद्ध सुक्खाइ वरमाणणं । कुणइ कम्मिंधणं पुंज पज्जालणं ॥ ६ ॥

[नित्य पूजा J. G. R. K. Bombay.]

have also been taken from similar works, but I am, at present, unable to trace their sources.

§17. Among the thirty seven short Sanskrit and Prākṛit works preserved on a paper manuscript in the Jaina temple at Jaswantnagar (U. P.), there are ten works in the Apabhramśa language, namely, *Suandhadasamī kahā*, *Rohiṇi vidhāna kathā*, *Muktāvali vidhāna kathā*, *Anantavrata kathānaka*, *Nirdoshasaptamī kathānaka*, *Pāshapaikahā*, *Jinapurandara kathā*, *Uddharaṇa kathā*, *Jinarātrividhāna kathānaka* and *Solahakāraṇa Jayamāla*. The first two of these works are the longest as they contain two *sandhis* each. The author of *Rohiṇividhāna kathā* is *Devanandi muni*. Nothing is known about the authors of the other works.[1]

§18. On the basis of the Introduction to the Bhavisayattakahā (G. O. S. No. 20) and the present article, a bibliography of the Apabhramśa literature so far discovered may be added.

[1] Extract from *Suandha dasamī kaha*.

जिण चउवीस णवेप्पिणु, हियइ धरेप्पिणु, देवत्तहं चउवीसहं ।
पुणु फलु आहासमि, धम्मु पयासमि, वर सुअंधदसमिहिं जहं ॥
पुच्छिउ सेणिएण तित्थंकरु, कहहि सुअंधदसमि फलु मणहरु ।
भणइं जिणिंदु णिसुणि अहो सेणिय, भव्वरयणगुणरयणिणिसेणिय ॥

+ + + +

जहि कोहु ण लोहु, सुहिण विरोहु, जिउ जर मरण विवज्जइ ।
नहि हरिसु विसाउ, पुण्णु ण पाउ, तहिणिवासु महु दिज्जउ ॥१॥
इति सुगंध दशमी कथा समाप्ता ।

Extract from *Rohiṇi vidhāna kathā*.

जिणवरु वंदेविणु, भाउ धरेविणु, दिव्व वाणि गुरु भत्तिए ।
रोहिणि उववासहो, दुरियविणासहो, फलु अक्खमि णिय सत्तिए ॥

+ + + +

रयणत्तय रिद्धहं, सीलविसुद्धहं, जीवहं जिणु सुमिरंतहं ।
देवणंदि मुणि भासइ, दुरिउ पणासइ, रोहिणि विहि पालंतहं ॥
इति रोहिणि विधान कथा समाप्ता ।

I.—LARGE WORKS.

1. Harivaṃśapurāṇa of Svayambhūdeva [Bh]
2. Paumacharia „ „ „
3. Tisaṭṭhipurisaguṇālaṅkāra of Pushpadanta. [Bh., B. K.]
4. Harivaṃśapurāṇa of Dhavala [S. K.]
5. Nemiṇāhachariu of Haribhadra [G. O. S.]
6. Mehesarachariu of Simhasena [J. B.]
7. Ārādhanā of Nayanandi [G. O. S.]
8. Sudarśana charita of Nayanandi [S. K.]
9. Yaśodharacharia of Pushpadanta [Bombay, Bh. and B. K.]
10. Nāyakumāracharia of Pushpadanta [B. K.]
11. Kathākosha of Srīchandra [B. K.]
12. Bhavisayattakahā [P. Munich, 1918; Baroda, 1923.]
13. Karakaṇḍūcharita of Kanakāmara [S. K.]
14. Pārśva Purāṇa of Padmakîrtti [B. K.]

II.—SMALLER WORKS.

15. Paramātma prakāśa of Yogîndradeva [P.]
16. Yogasāra of Yogachandramuni [M. B.]
17. Śrāvakāchāra of Dewasena [with the writer]
18. Daśalakshaṇa Jayamāla of Raidhû [J. G.]
19. Deva, Śāstra, Guru and Pañchaparameṣṭhî Jayamālas [occurring in the 'Nitya Pûjā' J. G.]
20. Jayatihuyaṇa stotra of Abhayadeva sûri [P.R. III, p. 245.]

21. Sañjñā Mañjarî of Megheśvara sûri [G. O. S.]

22. Commentary on the above by a pupil of Hemahamsasûri [G. O. S.]

23. Vairasāmichariu of Varadatta [G. O. S.]

24. Paumasiricharita of Dhāhila [G. O. S.]

25. Antaraṅgasandhi [G. O. S.]

26. Chauraṅgasandhi [G. O. S.]

27. Sulasākhyāna [G. O. S.]

28. Bhaviya Kuḍumbaracharita [G. O.

29. Sandeśarāsaka [G. O. S.]

30. Bhāvanā sandhi [G. O. S.]

31. Dohākosha [G. O. S.]

32. Sugandhadaśamīkathā.
33. Rohiṇividhānakathā.
34. Muktāvalividhānakathā.
35. Anantavratakathānaka.
36. Nirdoshasaptamîkathānaka.
37. Pashapai kahā.
38. Jinapurandara kathā.
39. Uddharaṇa kathā.
40. Jinarātrividhānakathānaka.
41. Solahakāraṇa Jayamāla.

On a single MS. in possession of the Jaina temple, Jaswantnagar (U. P.).

42. Prāchîna Gurjara-kāvya Samgraha (G. O. S. No. XIII.)

III.—Works in which Apabhraṁśa portions or quotations occur.

43. Prākṛita Piṅgala [K. S.]

44. Nāṭya Śāstra of Bharata, Chap. 32. [K. S. No. 42].

45. Siddha Hemachandra, 8th Adhyāya [G. C.]

46. Kumārapālacharita of Hemachandra (G. C.)

47. Prākrit Sarvasva of Mārkaṇḍeya [P.]

48. Sarasvatîkanṭhābharaṇa [P.]

49. Daśarûpa of Dhanañjaya [P.]

50. Dhvanyāloka of Ānandavardhana [P.]

51. Vikramorvaśî of Kālidāsa, Act. IV. [P.]

52. Prabandhachintāmaṇi of Merutuṅga [P.]

53. Vetāla pañcha viṁśatikā.

54. Siṁhāsanadvātriṁśikā.

55. Kumārapāla pratibodha of Somaprabha [P.]
[Pp. 3, 25, 38, 39, 57 and (1) Jîvamanaḥ karaṇasaṁtāpa kathā
(2) Sthûlabhadra kathā
(3) Daśārnabhadra kathā.]

56. Upadeśa Taraṅgiṇî of Ratnamandira (P. Benares) [Pp. 1, 64, 70].

57. Supāsanāha charia of Lakshmaṇagaṇi [Benares, 1918].

Abbreviations used in the bibliography, which indicate the places where MSS. are known to exist, the publication, or the source of the writer's information.

Bh.=Bhandarkar Institute, Poona.

B. K.=Balatkāragaṇa Jain Bhaṇḍār Kāranjā (Akola-Berar).

G. O. S.=Introduction to the Bhavisayatta kahā, published in the Gaekwāḍ Oriental Series No. XX.

G. C.=Government Central Book Depot, Bombay.

J. B.=Jaina temple of Bijnor (U. P.)

J. G.=Jaina Grantha Ratnākara Karyālaya, Bombay.

K. S.=Kāvyamālā series, Bombay.

M. B.=Maṇikachandra Digambara Jaina Granthamālā, Bombay.

P.=Published.

P. R.=Peterson's Report of Sanskrit MSS. Vol. III.

S. K.=Senagaṇa Jaina Bhaṇḍar, Kāranjā, (Akola-Berar.)

DEPARTMENT OF INDIAN VERNACULARS.

IDENTITY OF THE PRESENT DIALECT-AREAS OF HINDUSTAN WITH THE ANCIENT JANAPADAS.

DHIRENDRA VARMA, M. A.,
Lecturer in Hindi.

1. The vernacular of the people of Hindustan[1] consists of a number of dialects. According to the Linguistic Survey of India[2], these dialects form four groups, and each such group is regarded as a separate language in the Survey. Thus, Hindī is said to be the amalgamation of two entirely different languages, which have been given the names of Western Hindī and Eastern Hindī. Western Hindī has five dialects under it, *viz.*, Hindustānī, Bāngarū, Braja Bhāshā, Kanaujī, and Bundēlī; while Eastern Hindī has only three, *viz.*, Awadhī, Bāghēlī, and Chhattīsagarhī. Bhojapurī, Maithilī and Maghaī dialects are grouped together under the name o Bihārī language. Finally, Rājasthānī is regarded as a

[1] Hindustan is used in its restricted sense here. It signifies the whole valley of the Ganges with its tributaries as far as Bhagalpur in the east. It thus roughly includes the modern province of Delhi with the Punjab districts of Sirhind, the United Provinces of Agra and Oudh, the province of Behar excluding Orissa, the Central Provinces leaving out the four Marāthī speaking districts, the Central India Agency and the Rajputana Agency. The word is used in this very sense by Sir G. A. Grierson in his Modern Vernacular Literature of Hindustan, preface, p. 8.

[2] Linguistic Survey of India, edited by Sir G. A. Grierson,
Vol. V., Part II.
Vol. VI.
Vol. IX., Parts I, II.

separate language with Mālawī, Jaipurī and Mārwāṛī as its chief dialectic varieties. Now the areas in which these dialects are spoken coincide almost completely with the ancient Janapadas of Madhyadēśa[1], the name by which Hindustan was called in Pre-Mohammadan days. The connection was not lost altogether during the Budhist, the Hindu and even in the Mohammadan periods.

2. Starting with the dialects of Western Hindī, *Hindustānī* has naturally the first place. As a local vernacular it is spoken in Western Rohilkhanda, the Upper Gangetic Doab and the Punjab district of Ambala. This area coincides almost completely with the ancient Kuru country. It is point of some interest that the purest form of the dialect is spoken in the vicinity of the district where Hastināpura, the ancient capital of the Kuru country was once situated.

This dialect is virtually, the lingua franca of the Indian continent, leaving out the extreme southern land of the Dravidas of course. The whole Urdu literature as well as the rising modern Hindī literature is modelled on the grammatical structure of this dialect. The reason is not far to seek. During the Mohammadan period, Delhi was the capital of India and thus the dialect of the surrounding districts rose into importance and was carried away far and wide. The influence continues to this day.

3. *Bāngarū* dialect, which is a mixture of Hindustānī with the Punjābī and the Rājasthāni languages, is spoken in that part of the ancient Kuru country which was given to the Pandavas by their Kaurava brethren. It was here that Indraprastha, the rival of Hastināpura,

[1] J. R. A. S., 1904, P. 83.
Fa-hian, Chap. XVI.
Alberuni, Vol. I. P. 198.

arose. In the Hindu and the Mohammadan periods, the cities of Thanesvara and Delhi were its representatives. The latter was once more destined to be the capital of the Indian Empire. This area includes the sacred land of Brahmāvarta[1] of ancient times.

Just as Hindustānī is spoken along the upper course of the Ganges, so Bāngarū may be said to be spoken on the banks of the sacred Saraswati. The two areas are separated from each other by the blue Yamuna.

4. *Kanaují* is at present the dialect of the east central Doab and the country to its north as far as the Himalayas. The area represents the ancient Panchāla land but it has been much compressed of late by the expansion of Awadhī and Braja dialects on its either sides. To have a correct idea of the extension of the Panchāla country we shall have to include a few districts from both of these neighbours. The centre of the dialect is the city of Kanauja, which is not far from the site of Kampilā, the capital of King Drupada of the Panchālas. Like the ancient Panchāla land, the area is still divided by the Ganges into the northern and the southern portions, though a major part of the northern Panchāla tract, including the site of its capital Ahikshētra, has come under the influence of Braja Bhāshā.

This influx of Braja Bhāshā to the north of the Ganges is perhaps due to the constant flow of the people of this part to the sacred places of Mathura and Brindavana. Even to this day people annually visit these centres of Braja Bhāshā in very large numbers. Besides, there was no capital city in this part of the country in later periods, Ahikshētra having vanished with Budhism. Such a centre would have helped much in keeping the individuality of this portion distinct from its neighbours.

[1] Manusmriti, II. 17.

5. As opposed to Panchāla, the old Śūrasena country must have been smaller than what the Braja-area represents it to be. *Braja Bhāshā* is at present spoken in the west-central Doab and also in the country to its north and south. It has already been stated that the encroachment of this dialect to the north of the Doab beyond the Ganges is of a recent date, the river being the natural boundary on this side. Towards the south also it has extended much beyond its proper jurisdiction. The purest form of the dialect is spoken along the banks of the Yamuna, near Mathura and Brindavana.

It is true that throughout the Hindu period Kanauja retained its supremacy as a political, literary and even social centre of Hindustan, and for that matter of the whole of India, but Mathura was the religious centre; and we know religion is above everything else in this country. Moreover, the literary revival at Kanauja in the Hindu period was confined to the classical Sanskrit which could be understood only by the select few; so also its social dignity was extremely orthodox and aristocratic, but the establishment of the Krishna worship in Braja at about the same period and its revival by the Vaishnavas in the Mohammadan times were popular movements and had far-reaching liberalising effect both on literature as well as on society. The Vaishnava literature of the Braja Mandala is responsible to a great extent for the expansion of the local dialect beyond its natural boundaries. Only half a century back, Braja Bhāshā was the literary language of Hindustan. The place has been usurped of late by the modern Hindustānī.

As political centres both Mathura and Kanauja were completely destroyed by the early Mohammadan invaders, but Mathura had its rebirth in the beautiful city of Agra, the city of the Taj, which once rose to become the capital of the Mughal Empire, while the mighty Kanauja, the world

famed Canogyza of classical geography, seems to have attained Nirvana. To-day, a province is named after Agra, but what is Kanauja, not even a district town.

6. Of all the Janapadas of Hindustan, Kosala or Awadh has retained its individuality to a great degree even upto the present day. During the Mohammadan period, when all these ancient divisions were confused in a way, Awadh ultimately made itself separate under its famous Nawabs. To-day, under the British rule, the Talukedari system has kept it aloof from the sister province of Agra.

But the present day Awadh, as represented by the *Awadhī* dialect as also by the political sub-division, is not quite the same as the ancient Kosala. It has shifted towards the west and the south, thus slightly encroaching upon the old Panchāla and Vatsa countries. Its eastern boundary once touched Vidēha[1] but between the two now intervenes the dialect area of Bhojapurī. Kosala was situated on the Sarayu[2] but Oudh should be described as being situated on the Gomati. Ayodhya, the ancient capital, is at present just near the eastern boundary of the dialect area, where Awadhī ends and Bhojapurī begins.

There were several causes of the westward shifting of this dialect area, the first and the foremost being the removal of its capital from Ayodhya to Śrāvastī. The latter was the capital of Kosala during the whole of the Budhist period, and its influence on the life of the people must have been considerable. It should be remembered that Śrāvastī was much farther up towards the north-west in comparison to Ayodhya. During the Mohammadan times the centre of the activities of Awadh came down to Lucknow, which too is considerably towards the west. Even

[1]Śatapatha Brahmaṇa, I. 4. i.

[2]Rāmāyaṇa, I. 5. 5.

to this day Lucknow is the most important city not only of Oudh but virtually of the whole of Hindustan.

In ancient days, Kosala was perhaps divided from Panchāla by the extensive forests called Naimishāraṇya, where the great Bhārata was repeated by Sauti to Kulapati Śaunaka. When these forests were cut, the people of Kosala seem to have occupied the land, for they were expanding in that direction at the time.

7. Since the revival of Hinduism, Kāśī, the city of Viśvanātha, has been the centre of religious activities. To a modern Hindu, it is the holiest place in the whole land of Bhāratavarsha. In very ancient times, the court of the kings of Kāśī was a great centre for religious discourses; its rivalry with Vidēha was very great in this matter. The banks of the holy Saraswati or the sacred forests of Naimishāraṇya may dream of their past glory but the city of Viśvanātha even to-day stands supreme, equally for old learning and religious sanctity. It is, therefore, natural that the solid dialect area of *Bhojapurī*, the vernacular of the country round about Kāśī, should be so predominant. Just as the religious centre of Mathura has pressed back the Kanaujī dialect from its natural vicinity, so has Bhojapurī encroached upon its neighbours, *viz.*, Awadhī and Maithilī. The dialect has also sent a branch towards the south-east to Chhota-Nagpur but this is only a recent expansion. Here, the native population still consists of Kols and Santhals and the area is covered with extensive forests.

Leaving aside the small city of Jaunpur, the Mohammadan kings did not make this area the centre of their activities, hence it had no political importance during the Mediæval times. At present the area is hopelessly divided between the two provinces of Agra and Behar and these boundary people are looked down upon by those who are in power. The

area is roughly separated from Maithilī and Maghai areas by the rivers Gandaka and Son respectively. The Sarayu flows across the whole tract. In the south, the Son is the natural boundary.

8. Inspite of so many vicissitudes, Mithila or Vidēha of the ancient days, still keeps its individuality intact, though its fame as a seat of learning and scholarship has paled before that of Navadvīpa and Kāśī. The area of *Maithili* dialect more or less coincides with Mithilā of old. In Budhist times, it was divided into tribal republics. In the Mohanmadan period, it did not take any part in the politics of the country. Like a retired scholar, Mithilā never aspired to take a lead in controversies, be they political, social or religious.

9. The dialect area of *Maghai* almost exactly corresponds with the ancient land of Magadha. Like Pataliputra, the present capital Patna is still a boundary town. Magadha had considerable importance during the whole of the Budhist period. It was from this land that Budhism spread throughout India, and beyond to Burma, Cambodia, Java, China, Japan, Tibet, Central Asia and Afghanistan. It was the seat of the empires of the Mauryas and the Guptas. Even in the epic times, Jarasandha had similar aspirations but they could not be realised on account of the rising power of the western Janapadas.

10. According to the present survey, no dialect area marks out the Anga country. But this ancient country cannot be lost to us, for it was alive up to very recent times as Champā of the Budhist period and Bhagalpur of the Mohammadan times.

About the southern Janapadas of Hindustan, our knowledge is still limited. Their ancient capitals are not so well-known to us. These vast territories are still covered with extensive forests and are, on the whole, sparsely populated.

11. Strictly speaking, Chhattisagarh is beyond the natural boundary of Hindustan, but linguistically it is within it, for its dialect *Chhattīsagarhī* is a variety of Eastern Hindī. The area is outside the Ganges watershed, being situated on the banks of the Mahanadi which flows across Orissa and falls direct into the Bay of Bengal. This dialect area represents the ancient Dakshiṇa Kosala. In simplicity, the people may be compared with the Bhojapuris who are immediately to their north. The aboriginal people are Gonds and the land is known after them as Gondwana, a name well-known during the Mohammadan times.

12. *Bāghēlī* is another of the Eastern Hindī dialects. It is spoken in Central India to the south of Oudh. The centre of the dialect is the Rewah state of the Bāghela Rajputs, after whom it is named. The upper course of the river Son falls in this tract. No ancient Janapada can be mentioned in the centre of this area, but so much is certain that round about the place where *Bāghēlī* meets Awadhī was the Vatsa country with its once famous capital Kauśāmbi. The site of Pratishthānapur that legendry capital of the Chandravamśis, is also situated near its northern boundary. Since the time of the Mohammadans the city of Allahabad feebly represents the vicinity of these famous capitals and is at present the capital of the United Provinces of Agra and Oudh.

13. There is no doubt that the *Bundēlī* area represents the ancient Chedi land, whence hailed Śiśupāla, the born enemy of Krishna. The Betwa is the chief river of this region. This area contains the famous city of Mahoba of the Alha-Udal cycle. In mediæval times, the Hindu kings of this country fought many a tough battle against the emperors of Delhi. To its immediate north is the Kanauji area.

It should be remembered that the extension of Bundēlī and Bāghēlī dialects beyond the Narbada appears

to be of a recent date. These areas gained much importance at the time of the Mohammadan invasion, when the Hindu kings were driven from their hereditary kingdoms in the fertile Gangetic plains and had to seek shelter in these forest-clad hilly regions.

14. Malwa is a very ancient land. Its old name was Avanti. It is a high plateau, bounded on the south by the Vindhya range and sloping gradually towards the Gangetic basin. Avanti is now represented by the dialect area of *Mālwī*. Of late, the dialect has advanced to the south beyond the Vindhya and the present boundary is the river Tapti and the Satpura range. It will appear a little strange that water falling in such distant cities as Bhupal, Indore, Ujjain and Udaipur should come ultimately to the Ganges.

The Bhojas of these southern regions are mentioned in the Aitarēya Brāhmaṇa.[1] Narwara, the capital of Rājā Nala, Vidiśā where the plot of the famous romance of Bāna is laid, Ujjainī the city associated with the names of Vikramāditya and Kālidāsa, and Dhārā the seat of the last revival of Sanskrit studies, are some of the most important ancient cities of this area. The well-known stūpa of Sanchī is also here. Malwa was always an important province during the Mohammadan period. At present, the area is divided into a number of Hindu states, Indore being the chief of them.

Bhils are the aboriginal tribes of the hilly parts of this country. They live in large numbers in the Vindhyana forests.

15. The area of the *Jaipuri* dialect represents the Matsya country of the epic age. It was counted with Kuru, Panchāla and Śurasēna Janapadas and with them it was included under the common name of

[1] Aitarēya Brāhmaṇa, 38. 3.

Brahmarshidēśa[1]. The Haroti sub-division is a later expansion of the main people. The royal families of Kota and Bundi are also offshoots of the central house at Jaipur. Both in the ancient and the Mediæval periods, Jaipur and Malwa were the bases of the people of Hindustan for their excursions to Gujrat and the Deccan.

16. Mārawāra, the uninhabited Marudēśa of the ancients, is a vast desert country beyond the Aravali hills. This was occupied by the Kshattriyas of Hindustan when they were finally driven out from the plains by the victorious invaders. *Mārawārī* is the dialect of this tract. Mārawāra may be said to be beyond Hindustan proper. The Mēwarī area, which is a sub-division, should not be included in it. Mēwara cannot claim very great antiquity but with a single fort of Chittor its importance in the history of India can never be forgotten. To its south-west, beyond the Salambar hills, is the fair land of Gujrat.

17. Thus, an attempt has been made to show how the present dialect areas of Hindustan almost completely correspond with the ancient Janapadas of Madhyadēśa. Attention has also been drawn to the fact that this link was more or less unbroken during the Buddhist, Hindu and even the Mohammadan periods.

How could these Janapadas keep their identities separate for at least about three thousand years is a problem which needs a separate and a detailed treatment. Here only a few surface facts have been mentioned in this connection. Firstly, the very nature of these Janapadas, the ancient colonies or settlements of the Aryans, encouraged the existence of their separate identity. On the banks of important rivers, the forests were cleared and the settlements were made at convenient places, with single cities called *nagaras* or *puras* as their capitals. All the activities of

[1]Manusmriti, II. 19.

the settlement were concentrated at one point, namely the capital.

18. This sort of concentration continues to the present day, though the particular places may have shifted several times. In place of Indraprastha, the capital of the empire of Yudhishṭhira, we had Thanesvara and Delhi, also capitals of big empires. In place of Mathura, Agra has come to the fore since the Mughal times. If Kampilā and Ahikshētra were completely lost in oblivion, Kanauja, the glorious capital of Harsha's empire, took their place. Farukhabad, the Mohammadan substitute of Kanauja, could not fill its place when the latter was destroyed in its turn. This was perhaps due to the vicinity of Agra and Lucknow on its either sides. Lucknow is the unrivalled city in Oudh, what Ayodhya once was in Kosala. Kasi stands unchanged since very early times. Rājagriha, the capital of Magadha, was replaced by Pataliputra ; the latter with its slightly changed name Patna is even to-day the capital of Behar. Perhaps the mighty Pataliputra could not see any rival in its vicinity, hence the absence of any important town in Mithilā. Both Janakapur and Darbhanga seem equally dreamy and unreal to the present-day people. If the dialect area of Anga could be restored, Champā of the Budhist days and Bhagalpur of the Mohammadan and even modern times could be counted as its centres. About the capitals of the southern areas, much is not known but Ujjain in Malwa and Viratanagara, Amber and Jaipur in the Matsya country are too well-known to require any special mention.

19. Moreover the people of Hindustan are not migratory by habit. To counteract it, there have been sweeping human floods and other disturbances. In such cases what most probably happened was that the people bent down and the flood passed over them. Of course, there must have been some losses as well as additions but gradually the old people assimilated the new elements

and again twined round their capital, be it Ayodhya, Srāvāstī or Lucknow. This is why the ancient Janapadas of Kuru-Panchāla, Śūrsēna-Matsya, Kosala-Kośī, Vidēha-Magadha, Dakshina Kosala-Vatsa, and Chēdi-Avanti, which flourished in the tenth century before Christ, are still living in the twentieth century after him in the dialect-areas of Hindustani, Kanaujī, Braja Bhāshā, Jaipurī, Awadhī, Bhojapurī, Maīthilī, Maghaī, Chhattisagarhī, Bāghēlī, Bundēlī and Mālwi respectively.

20. In face of the overwhelming proofs in favour of the proposition it may be hoped that certain discrepancies, *e.g.*, the loss of the dialect-areas representing the Anga and Vatsa Janapadas, could be made good if another thorough and accurate survey were made under the supervision of experts. It should be remembered that the present linguistic survey is after all a pioneer attempt of its kind. It is a strong proof in favour of the suggestions made here that the survey, which was not made with this motive, should so thoroughly reveal the existence of the different people as they once flourished in very ancient times. In fact, a map of the present dialect-areas of Hindustan prepared on the basis of the data gathered in the light of today, appears to be a map of this country of the time when the great battle was fought on the fateful field of Kurukshetra[1].

[1] For Hindi version of the paper see N. P. Sabha Journal Vol. III, Part 4.

Chart showing the existence of the ancient Janapadas at different periods under different names.

Serial No.	1000 B.C. *Ancient Janapadas* according to the Mahābhārata.	600 B.C. *Kingdoms in early Budhist Period* according to Vinaya Texts.	600 A.D. *Kingdoms in the Hindu Period* according to Huentsang's Travels.	1600 A.D. *Divisions in the Mohammadan Period* according to Ain-i-Akbari.	1900 A.D. *Modern Dialect-areas* according to Linguistic Survey.	Serial No.
1	Kuru ...	Kurū ...	Sthānēśvara ...	Delhi ...	Hindustānī ...	1
2	" ...				Bāngaru ...	2
3	Panchāla ...	Panchālā ...	Kānyakubja ...	...	Kanaujī ..	3
4	Surasēna ...	Surasēnā ...	Mathurā ...	Agra ...	Braja Bhāshā ...	4
5	Kosala ...	Kosalā ...	Ayodhyā ...	Awadh ...	Awadhī ...	5
6	Kāśī ...	Kāsī ...	Vārāṇasī ...	...	Bhojapurī ...	6
7	Vidēha ...	Vajji-Mallā ...	Vaiśāli ...	...	Maithilī ...	7
8	Magadh ...	Magadhā ...	Magadha ...	Bihar ...	Maghaī ...	8
	D. Kosala ...	...	Mahā-kosala ...	(Gondwana) ...	Chhattīsagarhī ...	9
10	Vatsa ...	Vamsa ...	Kauśāmbi ...	Allahabad ...	Bāghēlī ...	10
11	Chēdi ...	Chētī ...	Jējāka Bhukti ...	...	Bundēlī ...	11
12	Avanti ...	Avantī ...	Ujjainī	Malwa ...	Mālwī ...	12
13	Matsya ...	Machchhā ...	Pāryātra ...	(Amber) ...	Jaipurī ...	13
14	Marudēśa ...	...	Gurjara ...	(Marwar) ...	Mārawārī ...	14

DEPARTMENT OF PHILOSOPHY.

THE DOCTRINE OF CONSEQUENCES

IN

MARTINEAU'S ETHICS.

N. C. MUKERJI, M.A.,
Lecturer in Philosophy.

Martineau develops his intuitional position by pointing out, ***first***, that it is the inward spring of action that gives value to it. An action, according to him, unfolds the following stages: (1) the sentiments whence it springs; (2) the muscular movement in which it visibly consists; (3) the consequences in which it issues. If we cut out the first, the other two, he points out, lose all their moral quality; "the muscular movement becomes spasm or sleep-walking; the consequences become natural phenomena." But not so, if we stop at the first; "else would guilt return to innocence by being frustrated, and goodness go for nothing when it strives in vain.[1] *Secondly*, it is pointed out that the knowledge of right and wrong as revealed in a gradual ranking of our springs of action as higher and lower, is immediate and underived. It is *sui generis* and cannot be resolved into any other order of knowledge. Questioned as to his proof of it, Martineau's principal answer is an appeal to inward experience. "To the very nature of moral discernment it is essential," he points out "that it be spontaneous, ready to meet the first occasion of moral experience, and that it be not therefore itself a product of experience. The more we appreciate what ***obligation*** means, the more shall we rest in the psychologically indigenous

[1] *Types of Ethical Theory*, Vol. II. pp. 25-6.

character of its conditions, without any hankering after the process of derivation for them."[1]

Having thus made sure of his intuitional basis, Martineau proceeds to face the argument from consequences in morality. He expressly repudiates working out a code of morals from merely intuitive data. There are two chief types of ethical doctrine, he points out, "of which the one betakes itself to the inward impulses, and finds an order of natural ranks among them; while the other resorts to the outward products in conduct, and applies a calculus of happiness for their advancement." "Notwithstanding" he continues "their seeming opposition, each doctrine speaks with a telling voice to some part or other of our nature......And each too, it must be confessed, seems to leave us with a want unsatisfied." "Can we then" he enquires "distribute to each its proper part? Or must they treat one another as irreconcilable enemies, and fight it out till the sole empire has been awarded by the reason of mankind?"[2]

How then does Martineau distribute the proper parts and conciliate the enemies? The most considerable passage where Martineau discusses the appeal to consequences occurs in *Types.* Vol. II, pp. 275-6.

Martineau allows of two kinds of appeal to consequences. Before we take it up, however, we should note Martineau's division of the *effects of action* into two classes. "First, there is the direct gratification of the impulse, whence the action proceeds; and secondly, there are the indirect and collateral consequences reflected back upon us from the world around on which the act is thrown, and where it sets new agencies at work"[3]. The first kind of appeal to consequences allowed by

[1] *Types*, Vol. II. p. 73.
[2] *Seat of Authority*, pp. 79-80
[3] *Types*, Vol. II. p. 74.

Martineau deals with " the direct gratification of the impulse whence the action proceeds" (here, we are under the first head of Martineau's classification of the effects of action—"the direct consequences", as he puts it), such as the pleasures of knowledge following on the exercise of the impulse of knowledge, the pleasures of ambition, following on the exercise of the impulse of ambition, the pleasures of sympathy following on the exercise of the impulse of sympathy, and so on. "Of what kind the gratification (of the impulse) will be we do not know beforehand[1], but after we had the gratification, in the thought of the impulse, the gratification is implied. "In proportion as the springs of action are self-conscious, they contemplate their own effects, and judgment upon them is included in our judgment of the disposition". Thus we can appeal on behalf of an impulse, to the pleasures of its gratification, without being hedonists ourselves. "The computation (of pleasurable and painful consequences) is already more or less involved in the preference of this or that spring of action[2]. "Prudence" and " Expediency " thus are brought back into the Intuitional fold, baptised into an appreciation of the value of things in themselves and purged of their hedonistic leaven. We can, for the sake of clearness, speak of a higher or lower "Prudence" and "Expediency", if we like, but they are there.

The second kind of appeal to consequences allowed by Martineau has reference to the situation where, after selecting the spring of action, we are in doubt as to the particular manner of satisfying it. (Here we are dealing with the second head of Martineau's classification of the effects of action—"the indirect and collateral consequences reflected back upon us from the world

[1] *Types*, Vol. II. p. 73.
[2] *Types*, Vol. II. p. 275.

around on which the act is thrown, and where it sets new agencies at work"). We have a number of courses open as to how best to be benevolent, *e.g.*—Shall I help a needy person with ready money? Shall I give it all together, or in instalments? Or, shall I help in kind? "These questions," points out Martineau, "it would be absurd, and, except to a fanatic, impossible to settle by any pretended intuitive light; they can be resolved only by careful study of each scheme in its natural working on the well-being of all whom it affects." Thay can only be settled, in other words, by practical knowledge. As Martineau continues: "If conscience selects the right affection, utility determines the fitting action; nor, without consulting it, is there any guarantee against the perpetration of well-intended mischiefs, which may bring the purest impulses into contempt. Viewed in this relation, the second doctrine supplements the first, and steps in to remedy its imperfect competency. Only, it must not enter before its time: not till conscience has spoken, is utility to be taken into counsel; it has a diploma for the executive Art of Ethics; but is an impostor in the primary science."[1]

It is, however, in a desire not to compromise conscience that Martineau is led in his exposition here to sharply antithetical statements, which suggest that he is wrenching things out of their true joint. The distinction between a well-meaning fool and a practically successful man, he says, is one of mere *judgment* and not of *character*. But if we succeed in converting the fool by "intellectual persuasion" and not "the machinery of moral correction", we surely cannot speak of our having saved him *in future*, as Martineau has it, from a blunder only and not from a sin[2]. Such a statement will itself be a blunder, if not worse!

[1]*Seat of Authority*, p. 81.
[2]*Seat of Authority*, p. 81.

Martineau, it must be admitted, leaves in his standard ethical writings (the *Types* and also the *Seat of Authority*) the relationship between Intellect and Morality very dubious. We, however, do not have Martineau's whole mind here. The complementary thought without which the sharply antithetical relation of intellect and morality given above becomes misleading, we have in a letter of Martineau's on the subject[1]. Speaking to this very point, Martineau writes: "Strictly speaking this is rather a *rational* than a *moral* act;" "but", he adds, "it becomes moral at second hand, because reason itself cannot exist, without responsibility in a nature entrusted with itself". The letter from which we have made the extract was written in reply to criticisms. But this complementing of his position was not a later addition, in the nature of an after-thought. In one of his earliest essays, we find the following:—"There are reasons, unchangeable as the corporal frame of man, why opium should not be taken as an article of food, and why cousins should not intermarry. But the grounds of prohibition in these cases are *rational*, not *moral*; they are found in the outward effects, not in the inward sources, of conduct; and only when its outward effects are *known* to the agent, so as to enter among its inward sources and modify its meaning, does he pass from *unwise* to *immoral*."[2] That the "unwise" after we have knowledge of it becomes "immoral" and the outward effects of conduct, *after they are known* to the agent, enter into its inward sources and modify its meaning—these are the complementary parts of his doctrine that we have to remember, if we are not to convict Martineau of an ultimate contradiction, as we read his summing up of the subject in the *Types*: "Thus, in the solution of all

[1]Quoted in Dr. Estlin Carpenter's "*James Martineau*", p. 559, f.n. 1.

[2]*Studies of Christianity*: Essay on "The Ethics of Christendom."

ethical problems, we have successive recourse to two distinct rules: *viz.*, the *Canon of Principles*, which gives the true *Moral Criterion* for determining the *right* of the case; and then the *Canon of Consequences*, which gives the *Rational criterion* for determining its *wisdom*. The former suffices for the estimate of *character*; but for the estimate of *conduct*, must be supplemented by the latter."[1]

Martineau has allowed of two kinds of appeal to consequences. The first is, as we have seen, where the consequence stands for the pleasure which the satisfaction or exercise of the impulse, from which the action proceeds, directly brings to the agent. Here we have only the *direct* consequences of action in view. The second kind of appeal is where the consequences decide as to the means to be employed for the satisfaction of an intuitively selected impulse. Here it is *indirect and collateral* consequences that are in view. But, when we examine our moral thinking, we shall find a third and perhaps the most important kind of the appeal to *indirect and collateral* consequences—*viz.* where we are in doubt as to our duty. We have here a number of competing springs to choose from, and do not know which should be selected under the circumstances. We therefore proceed to discover it by a following out of the indirect consequences of each competing spring and thus comparing them all together. Does Martineau allow of this, the most important type of the appeal to consequences? Martineau, it is true, does not discuss it in so many terms; but it is implied in his doctrine of moral judgment. Martineau, for example, points out that his table of springs is not to be taken irrespective of the context of our circumstances. "We are to accept," he says, "our rival incentives at the

[1] *Types*, Vol. II. pp. 275—6.

hands of circumstance and consider that our duty begins with their arrival".[1] This analysis of circumstances, what is it but another name for the weighing of consequences with a view to finding out the particular spring of action suited to it? We take up the consequences (the *indirect and collateral* consequences, be it remembered) of one spring after another and accept the one which does most justice to our circumstances and eliminate the rest. There is no other way but this of arriving at clarity and sanity of moral judgment. And this last and final appeal to consequences, we also find allowed and implicit in Martineau's theory of judgment.

To-day the concrete identity of motive and intention is one of the commonplaces of ethical thought. But the discussion of all the implications of the question in their wide ramification, and with an eye to fundamentals, seems to us to be Martineau's great contribution to the subject.

N. C. MUKERJI.

[1] *Types*, vol. II. p. 267.

THE REALISM OF DAVID HUME.

IN RELATION TO

CONTEMPORARY PHILOSOPHY.

ANUKUL CHANDRA MUKERJEE.

Lecturer.

Department of Philosophy.

INTRODUCTION.

Our age, inspite of its love of catholicism and humanitarianism is in many respects essentially individualistic, and our conceptions of human progress and our ideals of human freedom are vitiated by the same imperfections which characterised the thoughts of the eighteenth century. It is our indifference to the great lessons which the nineteenth century imparted to humanity at large, that is responsible in a large measure for the cataclysm to which we are driving ourselves—a cataclysm which overtakes humanity as often as man's attitude stops at the "everlasting no." The only difference between the disaster which is awaiting us in the near future and that of an earlier age appears to be this that while the latter affected Europe alone, the effects of the present "Aufklärung" are likely to be co-extensive with the world. The enlightenment has been aptly described as a "crisis and a revolution in the history of the world and of civilization, a movement that penetrates into all departments of life, that began in the eighteenth century and still continues, so far as the mass of the people in our day is in the condition which at that time was characteristic of the few." As a matter of fact in the name of a democratic ideal and human emancipation what we are

actually striving for is the unmolested supremacy of the individual over everything else; and it is perhaps high time for us to realize that an extreme emphasis upon the abstract individual can lead to anarchy but no democracy, and the self-refutation in this case is not less inevitable than in abstract universalism. If it is important to remember that the whole is for the parts, it is perhaps more important to insist that the parts have no significance apart from the whole and that everywhere order and harmony presuppose an amount of subordination and plasticity on the part of the individuals. There can be no law of the moment because an abstract moment is the very negation of that permanence and stability which a law implies. If the momentary fragments of my conscious life be not held together by the unity of a law which is more than these fragments, and similarly if the caprices of the exclusive individuals be not subordinated to a whole which is over-individual, there can be neither self nor society. In one case, it is a "mere manifold" without the unity of self-consciousness, as in the other it is an absolute anarchy without a community of purpose. Hence whenever the abstract individual of the moment is emphasized at the expense of the whole, it inevitably leads to disintegration in every department of life. In politics, it leads to the theory of "natural right" which essentially undermines the foundation of political obligation; in ethics, it leads to individualistic hedonism which ultimately dissolves morality into selfish pursuit of pleasure; in religion it leads to pietism which spurns at all creeds and insists on a non-ecclesiastical or private form of religion; and finally, in philosophy, it leads to scepticism and distrust of reason, thus overthrowing the ultimate principles of knowledge and experience. In fact, when Locke says that man is born with a title to perfect freedom, and an uncontrolled enjoyment of all the rights and privileges of the law of nature[1]

[1] *Civil Government, Ch. VII, Sec. 87.*

it is the application, in the political sphere, of the same principle which underlies his views on the "simple ideas," the principle namely, that the particulars have a nature of their own apart from the whole to which they may, but need not, belong. This is just what consistency requires. It is as impossible for Locke to give priority to the whole in politics while insisting on the supremacy of the parts in the theory of knowledge, as it would be impossible for Hooker and Grotius, Hobbes and Rousseau, to vindicate the superior claims of the individual in their politics and at the same time emphasize the importance of the categories in their epistemology, if they had taken up the problem of knowledge at all.

This individualism, which is characteristic of the empirico-realistic attitude of mind, is everywhere due to an imperfect view of the individual. It emphasizes an element of reality in its abstractness from the whole, and does not see, to borrow a phrase of Mr. Bosanquet, the self-transcendence of the individual. Each atom is supposed to be a hard nucleus impervious to others, and their relations to one another are then thought to be purely extrinsic; so that their belonging to one world is after all a mere accident and is not essential to their intrinsic nature. This is the real significance of individualism which is equivalent to abstractionism. The realistic mind, says Mr. J. W. Scott,[1] stands idly before the given...abandoning all attempts to construct it trying simply to *take* it, muttering to himself in succession, "just this", "this *here*", "this here *now*", "this *out* here now". This realistic temper, as he attempts to show through the doctrines of Bergson and Russell leads to the narrowness of current industrial movements of Europe. It favours the multiplication of small organisations "so that the individual

[1] *Realism and Politics*, article in the *Proceedings of the Aristotelian Society, 1917-18.*

who cannot get scope for himself in the service of a great wide state may be able to select a sphere which suits him and get scope there for that in him which the wider world has no use for." Mr. Scott has rightly traced the origin of individualism to the realistic attitude of mind, for the realistic abstraction of the external world from the knowing mind is but a particular application of a more general principle—a principle which underlies the common sense interpretations of experience as well as the realistic and the empirical methods in philosophy. .. ...

THE REALISTIC DOGMA.

The object of the following lines is to lay bare what appears to be the fundamental fallacy in some of the current streams of philosophical speculations. The semblance of advance which they are generally supposed to have made is due to our not realising the exact nature of Kant's answer to Hume, the consequence being a repetition of the "Humian fallacy". It is true that the elements of pre-Kantian empiricism have been already found to be present in pragmatism and contemporary realism, and the critics have been pointing out the gaps and shortcomings of the empirico-realistic analysis of experience. But the very fact that the modern speculations are apparently unaffected by these critical reflections indicates that the root-fallacy of the empirical philosophy has not yet been detected. In fact, the substantial correctness of Hume's position and its unassailability have been recognised not only by the realists and the pragmatists of our time, who avowedly build their speculations upon the basis laid by the Scottish sceptic, but this recognition has very often come from quarters where sensationalism and empiricism are supposed to be exploded doctrines. The necessary implication of this of course is, in the words of Dr. J. H. Stirling, that Kant's vast transcendental machinery is a signal

failure.[1] Kant's works, it is well known, were the results of reflections upon various problems of his time. His special intention was to enquire if the positivistic and mechanical view of the world were not ultimately reconcilable with the demands of moral and religious consciousness; and this spirit of mediation is prominently present throughout the arguments of the critique of Pure Reason. It may not be possible for all of us to accept his arguments and results in detail. His theory of the *a priori* elements of experience may be a remnant of the rationalistic school, his views on the thing-in-itself and noumenon may have been due to a realistic bias from which he never freed himself, and so on. But this should not blind us to his permanent contributions to philosophy, specially to epistemology; yet I fear this is just what has happened. The peculiar aspects of his teaching have exercised and are still exercising such a harmful influence upon many of his readers that they are slow to recognise the value and significance of even the central epistemological contentions of the *Critique*. It is necessary therefore to bring the permanent elements of Kant's philosophy into a focus which will at least have the use of determining the lines upon which alone the Kantian position admits of further elaborations. That such a focalisation is absolutely indispensable for any real advance of speculative thought is amply evident from this that the old exploded theories are again struggling for life and even supremacy in our own times, fortified by mathematical researches and outlandish dialectics. This circumstance sufficiently bears out Green's remark that each generation requires the question of philosophy to be put to it in its own language, and unless they are so put, will not be at the pains to understand them.

[1] *Mind*, *1885*.

In the following lines, I confine myself to the exposition and critical consideration of that *realistic dogma* which was at the basis of Hume's scepticism and which is the ultimate basis of every realistic or pluralistic metaphysics. Indeed to characterize Hume's philosophy as the self-refutation of sensationalism is to miss the deeper foundation of sensationalism itself. It was the realistic assumption of pre-Kantian empiricism which worked itself out in the hands of the Scottish sceptic whose failure to make Locke consistent was but an indication of the self-contradictory nature of the fundamental realistic dogma. The general impression that Hume's was a sensationalistic philosophy and that Kant laid bare the fallacy of the philosophy of abstract feeling has had its disastrous consequences. Unconscious of the deeper foundation of empiricism, and interpreting Kant's criticism as a mere intellectualistic retort to sensationalistic exaggeration, contemporary thinkers are falling victim to the same realistic dogma which Hume thought it beyond his power to abandon and which Kant found beyond his power to accept. This is surely subversive of the real object of philosophical activities. My aim therefore is to show, in however imperfect a form, that Kant's answer to Hume has thoroughly undermined the only basis upon which all forms of realism must ultimately stand, and consequently the realistic and empirical philosophies of our time, in spite of what value they may possess for students of philosophy do not represent a real development of thought. If we attempt a brief formulation of the underlying principle of empiricism it will be found to consist in the assumption that the "unconnected manifold" have a superior reality in comparison to their unity. From this assumption follow several others namely, that the object is but an assemblage of different sensations held together by the arbitrary bonds of association, the self

is likewise a bundle of perceptions which may as well be conceived as not forming such a bundle, and the relation between the object and the self is purely mechanical so that the cognitive relation which brings them together has no effect upon their intrinsic natures. In all these, the distinctions are emphasized at the expense of their unity, and the inevitable result is atomism. This atomism expresses itself in various forms in Hume. It is not only apparent in his account of the self and the world, but is the fundamental thought underlying his conceptions of the criterion of truth, the nature of abstract ideas, space and time, no less than his analysis of man's moral nature and political obligation. His method everywhere is the same. He picks out the momentary aspects of the concrete reality, considers them apart from each other, and emphasizes them in their abstract character to such an extent as to reduce their relation and unity into mere illusions or words without meaning. Hence his injunction that if in philosophy a word is used without meaning, the best course to expose it is to ask for the impression from which the idea has been derived. Nominalism, solipsism, individualism, and scepticism which are so characteristic of Hume's writings are but the natural results of this original abstraction. Now, Kant's answer to Hume consists precisely in pointing out the error of this abstraction. His transcendental enquiries aim at bringing out the conditions of the reality of the particulars, those *a priori* conditions which, though not clearly realized by us at every moment of our conscious lives, are yet presupposed by the particulars. Thus, in the *Critique of Pure Reason*, his contentions are that the manifold are what they are because of their spatial and temporal relations which bind them together, the object is what it is because of its relation to other objects and ultimately to the subject, an event is what it is

on account of its relation to another previous event, and so on.

When we come to contemporary philosophy in its realistic and empirical forms we find that inspite of the gulf that separates these modern thinkers from Locke and Hume, they are faithful followers of the latter so far as their fundamental tenet is concerned. This tenet is essentially that of Locke and Hume; namely, that all the existing things are "distinct existences" having no necessary relations among them. That is, the fundamental assumption of these current philosophical streams is that the different beings have substantial existences, and their relations are but extrinsic in the sense that they make no difference to the terms between which they hold. Like Locke's simple ideas they "carry with them in their own nature no visible necessary connections or inconsistency with any other simple ideas"[1] The consequences of this position in the current philosophy are similar to those of the Lockian and the Humian speculations—nominalism, solipsism and scepticism. Indeed it requires a little careful scrutiny to discover that the whole of the pre-Kantian empiricism has been revived in its essential respects under the names of pragmatism and neo-realism, while, the permanent contributions made to philosophy by Kant have been lost in the breathless haste for original system-building. It is true that the empirical method has been sometimes differently formulated. Thus Mr. Alexander points out that the word empirical is intended to mean nothing more than the method used in the special sciences, it is equivalent to experiential.[2] Similarly, Mr W. James identifies it with the natural science method, in his preface to the *Principles of Psychology*. But the philosophical contrast between non-empirical or *a priori*

[1] *Essay* ii. *23*, *3*.
[2] *Space, Time and Diety, Vol. I, p. 4.*

method and the empirical method can be articulated only when we formulate the former as that which goes from the whole to the part, from the unity to the diversity; while the latter is described as that which goes from the part to the whole, from the diversity to the unity. This contrast is accentuated in several places by James himself, when he says that the most pregnant difference between empiricism and rationalism is that empiricism means the habit of explaining wholes by parts and rationalism means the habit of explaining parts by wholes.[1] The difference, he points out further on, between monistic idealism and radical empiricism leads to a great question of vital importance "the question, namely whether all the relations with other things, possible to a being, are pre-included in its intrinsic nature and enter into its essence, or whether, in respect of some of these relations, it can *be* without reference to them." Empiricism according to him must decide in favour of the latter alternative, because when the manuscript is *on* the desk the relation of being "on" does not seem to implicate or involve in any way the inner meaning of the manuscript or the inner structure of the desk.[2] This externality of relation is the fundamental, and from the philosophical stand-point the most important, point which unites contemporary realism with pragmatism and distinguishes both of them from intellectualism, idealism and rationalism. "The theory which the realist finds used so frequently by his opponents" is "the theory of internal relations" which hold that "the parts or elements are all constituted by their relations to all other parts in the complex".[3] Realism, on the other hand, must insist

[1] *cf. Essays in Radical Empiricism, p. 41 ; A Pluralistic Universe, p. 7 ; Some Problems of Philosophy, p. 35* ; Preface to Höffding's *Problem of Philosophy.*

[2] *A Pluralistic Universe, p. 80.*

[3] *New Realism, p. 165.*

on the theory of the externality of relations and recognise that the terms are in no way altered by the relations established between them and that the entity does not lose its identity by being a constituent of different complexes. This, according to Mr. Russell, is the indisputable basis of realism. Thus it is clear that both pragmatism and realism look upon the world as a collection or aggregate in which all the existents are related to one another by the relation of *and*. This *and*, says Mr. Russell, represents a fundamental way of combining terms[1]. One is irresistibly reminded here of Locke's definition of substances as collection of ideas, or Berkley's conception of the idea entering into an external and non-modifying relation to the percipient mind, and finally of Hume's division of philosophical relations into two classes, those that depend entirely on the ideas and those that may be changed without any change in the ideas. Here in the pre-Kantian empiricism we already find traces of the theory of externality of relations, and it matters little whether the terms between which the relations obtain be called ideas or entities, impressions, or existents, sensa or character-complexes.

To put these contentions in a clearer light, we must try to ascertain, in a little more definite way, the exact nature of the movement which ended with Hume.

FROM HUME TO KANT.

The transition from Hume to Kant has been variously conceived. Hume is generally believed to have brought out the inner implications of sensationalism, and so the transition from Hume to Kant is characterised as one from sensationalism to intellectualism. Thus, Green concludes his searching criticism of empiricism with the remark that "the philosophy based on the abstraction of feeling...was

[1] *Principles of Mathematics*. p. 71.

with Hume played out," and the next step forward represented by Kant and Hegel was "an effort to re-think the process of nature and human action from its true beginning in thought". It is also customary to characterise the transition as one from scepticism to criticism, from empiricism to rationalism or finally from atomism to transcendentalism. These characterisations are of course all true in their own ways, but they do not exhaust the manifold features of the great epoch which Hume terminates, and what is more, they do not perhaps accentuate some of the momentous characters of that great movement. It does not appear to have been sufficiently recognised that underlying the surface currents there was another of deeper import and of more far-reaching consequences. This deeper movement of thought may be adequately described as a movement *from realism to idealism or from pluralism to monism*; and a closer inspection shows that it was not only the philosophy which was built upon the abstraction of feeling, but also the realistic and the pluralistic philosophies which were played out with Hume. The answers which Hume received at the hands of his German opponent was no doubt directly meant to refute the sensationalistic basis of his philosophy. But the answer touches far other aspects of Hume's philosophy of which neither the questioner nor the respondent was fully conscious. While engaged in drawing the legitimate consequences of the empirical principles of Locke's philosophy, Hume was unconsciously exposing the deficiencies of a realistic and pluralistic metaphysics. Similarly in answering the difficulties of a sensationalistic philosophy, Kant was unconsciously laying the foundation of an idealistic metaphysics and dealing a death blow to pluralism and realism alike.

Locke, Berkeley and Hume are generally known as representatives of empiricism and phenomenalism. But there was a deeper bond existing between them of which

their empiricism or phenomenalism was but a result. This was the common realistic foundation of their systems. In fact, Berkeley's system was idealistic only in name and aim. It cannot even be said to be what Prof. Royce calls a half-way idealism, as its fundamental assumption was through-and-through realistic. The realistic tenet of Berkeley's pseudo-idealism has worked itself out in contemporary realism, which has for its ultimate basis an assumption that formed Berkeley's intellectual heritage; but its incompatibility with his system Berkeley never detected. This will surely be challenged by the realists of our time. For, is it not the very mission of neo-realism, they will point out, to prove against Berkeley the independence of the experienced on the act of experience? Does not Berkeley together with other idealists commit the Verbal Fallacy of Psycho-physical Metonymy?[1] A negative reply has already been given to this. Thus Prof. Alexander[2] and Prof. Dawes Hicks[3] have drawn attention to the passage in which Berkeley too makes such a distinction. Prof. Laird again, in his brilliant article in the Mind[4] while indicating the numerous points of contact between Berkeley and the neo-realists goes so far as to declare that "it would scarcely be possible to conceive of a system which, in its intention, was more thoroughly realistic than Berkeley's." They have not however detected a more fundamental relation which binds neo-realism with Berkeley's philosophy, yet that is much more vital than anything that has hitherto been brought forth. What is this vital agreement?

Berkeley's central thesis that the *esse* of things is their *percipi* conceals a theory of independent entities

[1] *New Realism, p. 259.*
[2] *The Basis of Realism, p. 5.*
[3] *Proceedings of Aristotelian Society, 1911-12.*
[4] *(1916.)*

which is indeed the corner-stone of all realistic metaphysics. Inspite of what he says about the dependence of the things upon a percipient mind, the "ideas" and the mind perceiving them are supposed to enter into a temporary external relation to each other like impervious atoms which remain unmodified and uninfluenced by any casual relation subsisting between them. Mr. Joachim's description of the realistic view on the cognitive relation is instructive in this connection. "Atom on one side comes together with atom on the other side; but why *this* atom should be related to *that*, or indeed any atom to any other, is a question which cannot be answered. It cannot be answered, for there is no rational ground for the relation."[1] So long as this position is accepted, as a true representation of facts, one is inevitably on the realistic basis, and it is immaterial whether those atoms are called ideas, impressions, sensa or character-complexes. This atomism which was never doubted by Locke, Berkeley and Hume made their systems essentially incompatible with any form of true idealism. Mr. R. B. Perry then is right, over against such pseudo-idealism when he says that "If the idealist's polemic against realism is successful, we are left to conclude that experiencing *does* make a difference to facts. This is as truly the central contention of idealism as the contrary is the central contention of realism."[2] It is only to be added that the contrary assumption is also the ultimate foundation of pluralism no less than of empiricism, and so a realist has consistently to be a pluralist. Thus W. James has to admit on the one hand that "mine is essentially a mosaic philosophy, a philosophy of plural facts, like that of Hume and his descendants"[3] but on the other hand he finds that "radical

[1] *The Nature of Truth, p. 44.*
[2] *Neo-Realism, p. 105.*
[3] *Essays in Radical Empiricism, p. 42.*

empiricism has in fact more affinites with natural realism than with the views of Berkeley or of Mill."[1]

Hume, inspite of his differences from Locke and Berkeley, is one with them, so far as their realistic assumption is concerned. In him, however, that assumption appears in its absolute nakedness, shorn of the dogmatic and theological embellishments. The shortest and at the same time the clearest statement of Hume's philosophical basis is perhaps to be found in the following remarks of his in the section V on the immateriality of the soul; "If...any one should evade the difficulty by saying that the definition of a substance is *something which may exist by itself*...I should observe that this definition agrees to everything that can possibly be conceived, and never will serve to distinguish substance from accident, or the soul from its perceptions. For, thus I reason. Whatever is clearly conceived may exist; and whatever is clearly conceived, after any manner, may exist after the same manner...Again, everything which is different is distinguishable, and everything which is distinguishable is separable by the imagination...My conclusion from both is that since all our perceptions are different from each other, and from everything else of the universe, they are also distinct and separable, and may be considered as separately existent, and may exist separately, and have no need of anything else, to support their existence. They are therefore substances, as far as this definition explains a substance."[2] If we agree to make concession to the peculiar way in which Hume states his fundamental position, no realist would perhaps find it possible to give a clearer exposition of his philosophy within the limits of such a few lines as these. It is true that one of the vital points of difference between neo-realism

[1] *Ibid, p. 76.*

[2] *Treatise, p. 223.*

and its older name-sake consists in its protest against the substantialism of Locke and Reid. But, for all this, it clings to substantialism of the type which Berkeley and Hume found so essential to their systems, and while this position remains the same there is no reason why their conclusions should be reversed.

There are two more points with regard to which the contemporary realists and empiricists have failed to appreciate Kant's answer to Hume. The beliefs that reality is a creative process, a flux or pure becoming, and that mind is one among other finite things holding its place on equal terms with them, have found recognition with the majority of eminent thinkers of our time. Thus, for example as a protest against the indestructible entities of physics, Mr. B. Russell insists that "the world of immediate data is quite different from this. Nothing is permanent; even the things that we think are fairly permanent, such as mountains, only become data when we see them, and are not immediately given as existing at other moments."[1] Similarly Mr. Whitehead urges that the immediate fact for awareness is "Nature as an event present for sense-awareness and essentially passing. There is no holding nature still and looking at it."[2] For the realistic account of mind and its place in reality, we need but look at the unambiguous language of Professor Alexander: "For realism, mind has no privileged place in the democracy of things...Mind again is a form of time, because the mind-quality emerges out of the time element like all other empirical qualities."[3] Such passages are strongly reminiscent of the favourite tenets of pre-Kantian empiricism. The transcendental method of proof, as is well-known, was intended to bring out the inherent deficiency of a philosophy which sought to construct the house of experience

[1] *Our knowledge of the External world*, p. 104.
[2] *The Concept of Nature*, p. 14.
[3] *Space, Time and Deity*, Vol. II, p. 44.

out of a mere flux of ideas destitute of inner necessity or internal determination, and which regarded mind from the psychological point of view as one object among others. In fact, it is no violence to Hume's position to say that his was essentially a philosophy of becoming quite as much as a philosophy of "distinct existences". If he is never tired of insisting that all the particular perceptions "are different, and distinguishable, and separable, from each other, and may be separately considered, and may exist separately, and have no need of anything to support their existence"; he is equally emphatic in his assertion that the different perceptions "succeed each other with an inconceivable rapidity, and are in a perpetual flux and movement".[1] As to the dislodgment of mind from its privileged place of autocratic supremacy, Mr. Alexander and his followers are but celebrating with clearer consciousness a festival for which an elaborate arrangement was made by the author of the '*Essay concerning Human Understanding*'. Postponing the consideration of these aspects of contemporary thought, we may revert, for a moment, to that realistic dogma which, as suggested above, is the indispensable foundation of every realistic metaphysics.

THE REALS.

It has been rightly pointed out by the American Neo-Realists that the internality of relations and the universality of cognition are the grounds of metaphysical monism. It does not however appear to have been realised by them that the opposite theory, namely the theory of the externality of relations bears a close resemblance to the Humian principle that all our distinct perceptions are distinct existences, and that the mind never perceives a real connection among distinct existences. The difficulties which for Hume were insuperable arose ultimately

[1] *Treatise, p. 239.*

from his inability to abandon the belief in an unalterable impervious atomic existence. Kant's reply consisted precisely in pointing out that the connections, far from being external to the atomic existences, entered into their intrinsic nature, that each existence possessed a being not in its self-seclusion and unrelatedness but in its self-transcendence or relatedness to existences beyond itself. This Kant expressed by saying that the categories made experience possible. Take any single object and think away all the connections that hold between itself and other things, and that object reduce itself to a non-entity. "The more we remove," says Lotze, "from the conception of Being every thought of a relation, in the affirmation of which it might consist, the more completely the possibility of this distinction (between Being and non-Being) disappears."[1] "To be thus void of relation is just that in which we should find the non-entity of a thing if it was our purpose to define it." This was the ultimate consequence of Kant's investigation too. Things do not exist at first in separation from each other so that all connections between them would be mere fortuitous generalizations; on the contrary, their existence has no intelligible meaning except in relation to each other. What we call the real existence of the world is constituted by the various relations, spatial, temporal, causal etc., subsisting between things, and each thing is what it is only through its relations. To put this in the inimitable language of Green, "abstract the many relations from the one thing, and there is nothing. They, being many, determine or constitute its definite unity. It is not the case that it first exists in its unity, and then is brought into various relations. Without the relations it would not exist at all".[2]

It is a further consequence of this line of thought that there can be no real entity possessed of an intrinsic

[1] *Metaphysics, Vol. I. p. 39.*
[2] *Proleg. § 28.*

nature of its own which is not influenced by the various relations into which that entity may enter. All things are dependent upon other things in so far as their very nature is determined by those mutual relations. The possibility of an unalterable entity entering into different relations would be intelligible only if the being of that entity did not consist in relations; but once it is admitted that a thing is nothing apart from its relations to other things, the unalterability of an entity in different groups or relations could be maintained only by a manifest inconsistency. Yet, this is just what is implied by the theory of externality of relations. Realism, it has been insisted, must reject the premise that all relations are internal and recognise that while all things may perhaps be related, many of these relations are not constitutive or determinative; they do not enter into the explanation of the nature or existence of their terms.[1] Thus, for example the spatial relation between the book and the table is not a constitutive relation, because, as Mr. James points out, any book and any table may fall into the relation by their casual situation. But then the question inevitable arises: how is it that only a table and a book can fall into this relation and not certain other things? If the relation is a mere coincidence then there is no rational ground why this particular thing should fall into that relation with that particular thing. In fact the relation is not casual, it is as much the nature of the table to have the book upon itself as it is the nature of the book to be upon the table, just as it is the nature of the sun to warm the stone and the nature of the stone to become warm under the sun. To continue this example of Kant's, if the sun sometimes warms this stone and sometimes does not we should have to say that the sun has changed its nature; similarly if the table sometimes supports the book and sometimes does not we should

[1] *Neo-Realism, p. 33.*

also grant that the table has undergone a change of nature. It is no objection to say that though the table has the possibility of having the book on itself, yet the table would remain what it is even if no books were ever placed upon it. Because then this remark would apply to the sun as well. Both the table and the sun might be defined without reference to the book or the stone, but what is important to observe in such cases is that our definitions are not complete. As our knowledge of things increases, many of the relations which were formerly supposed to be non-constitutive and non-determinative are found to be intimately bound up with the nature of that thing. This evidently indicates the arbitrary nature of the distinction between intrinsic and extrinsic relations. "That for working purposes," says Mr. F. H. Bradley, "we treat some relations as external merely I do not deny, and that of course is not the question at issue here. That question is in short whether this distinction of internal and external is absolute or is but relative, and whether in the end and in principle a mere external relation is possible and forced on us by the facts...Every space...would be a whole in which the parts throughout are interrelated already in every possible position, and reciprocally determine one another...And from this the conclusion cannot be drawn that the terms are inwardly indifferent to their relations; for the whole internal characters of the terms, it seems, goes out, on the contrary, and consists in these."[1] The truth of this remark—which substantially reproduces the Kantian account of spatial relations—is forced upon us whenever we refuse to look at a thing simply as it is and enquire into its possibility.

It does not appear to have struck any of the neo-realists that inspite of their emphatic rejection of all mystical metaphysics and adoption of the scientific

[1] *Appearance and Reality*, p. 576.

stand-point, their own procedure implies a theory of reals which can hardly be distinguished from that of Leibnitz and Herbart on the one hand and that of Permenides on the other. In their zeal against the internality of relations which they consider as one of the grounds of idealism they have been led to propound a theory of simple entities which are as indefinable and chimerical as the absolutely exclusive Many of pluralism or the pure Being of mystical universalism. The simple entities, it is urged, may enter into this or that group but they do not belong to it, they depend on no relation, they are the entities at large and belong exclusively to no constituency.[1] As thus described it is difficult to see how these simple entities of the neo-realists differ from the "reals" of Herbart in the enjoyment of pure "position" void of all relations. Like the pure Being of the Eleatic school, each simple entity has a being of its own, "substantial and self-dependent, and the difficulty then is to drag it out of this state of ontological seclusion into the region of empirical reality with its thousand relations."

These remarks, it may be retorted, do not apply to the realistic conception of the independent simple elements which are not unrelated to one another. All that is claimed is that they do not depend upon those relations and "it is fundamentally characteristic of neo-realism to distinguish relation and dependence". Given two entities they will be dependent upon each other only when one is a part of the other, or implies the other, or is exclusively determined by a system in which it is cause, effect, or implication of the other. In the absence of these relations the entities retain their independence whatever other relations may subsist between them. Now the reply is that this distinction between relation and dependence is after all a matter of definition and is obtained by a restriction of their application

[1] *Neo-Realism, p. 129.*

to certain definite cases. But the question at issue is not whether we should *call* one set of relations as those of dependence and another set of relations as those of independence. The real question is whether there can be any relation between two terms which is so external that it does not affect the terms in any way. It has been said that the bare relation between entities is in the great majority of cases discovered before any dependence is proved. Thus, things may be together in space, may succeed one another in time, may be different, more, less, whether or not they are whole and part, cause and effect, or implier and implied. This position may be conceded at once, and yet it may be denied that a thing remains what it is whether it is co-existent or successive, more or less, in relation to another thing. In fact if there had been no fixed rule according to which one event can only succeed but never precede another there would be no consciousness of succession at all. To borrow the well-known example of Kant, had the relation of succession been really external to the nature of the positions of the boat moving down stream, so that the relation would make no difference to the terms, there could be no knowledge of objective succession at all as distinct from co-existence. It is not therefore immaterial for the terms which of the possible relations subsist between them. The relations, far from being extrinsic to the terms are constitutive, so that the same term in all its concreteness cannot be in different relations.

We are then left to conclude that the simple entities of the neo-realists are existences void of all relations and this is the inevitable implication of the assertion that the fact of their entering into any relation does not affect their independence in the least. If then neo-realism has to accept the theory of relationless existences, it is subject to those well-known criticisms which Permenides

and Leibnitz, Hume and Herbart have received at the hands of the idealists from Plato to Hegel, and from Kant to Lotze and Royce. Thus Lotze remarks "In reality it is impossible for that to enter into relations which was previously unrelated. For *a* could not enter into relations *in general*. At each moment it could only enter into the definite relation *m* towards the definite element *b*, to the exclusion of every other relation *u* towards the same element. There must therefore be some reason in operation which in each individual case allows and brings about the realisation only of *m*, not that of a chance *u*."[1] Indeed, Lotze's elaborate criticism of Herbart's position—which is but a slightly different formulation of Kant's criticism of Hume—is so thorough and convincing that nothing but an ineradicable prejudice can account for the revival of the realistic theory of pure being in contemporary philosophy.

[1] *Metaphysics, Vol. I, p. 50.*

DEPARTMENT OF MATHEMATICS.

ON VERTICAL AND HORIZONTAL PRESSURES ON A ROUGH CYCLOIDAL PULLEY DUE TO THE MOTION OF A HEAVY INEXTENSIBLE CHAIN OVER IT.

BY

A. C. BANERJI, M. A. and S. K. MUKERJI, B. Sc.

In a paper entitled "On some interesting results in connection with the motion of a heavy inextensible chain over a smooth pulley" by Mr. A. C. Banerji, published in the Bulletin of the Calcutta Mathematical Society, December 1924, total vertical and horizontal thrusts between the chain and the pulley were calculated, and it was found out that if the chain was made to move with an acceleration equal to one-third of gravity with certain initial conditions, the total vertical thrust between the chain and the pulley vanished. Again in another paper entitled "On pressure on a rough circular pulley due to the motion of a heavy inextensible chain over it," it was also found out that if an acceleration equal to one-third of gravity is imparted to the chain over a rough circular pulley with suitable initial conditions the vertical thrust would vanish. The horizontal thrust was there found to be independent of friction, being the same in value as in the case of the smooth pulley.

The object of the present paper is to take a rough Cycloidal pulley with vertex upwards and then to calculate the vertical and horizontal thrusts due to the motion of a heavy inextensible chain over it. It will be also found that in order to make the vertical thrust vanish, it will be necessary to impart an acceleration equal to one-third of gravity as before with suitable initial conditions. It is interesting to note that for vanishing of the vertical thrust, the same acceleration equal to one-third of gravity is needed in all the cases. The horizontal thrust was also found to be independent of friction.

We take the equation to the Cycloid to be $S=4a \sin\psi$, where S is measured from the vertex B and ψ is the angle

which the tangent at any point P makes with the horizontal tangent at B.

Let A be a marked point on the chain. Let the arc BA be S at the instant t.

Let P be any other point on the chain and let AP be 'σ'

Let the element PQ of the chain be $\Delta\sigma$

Let L and M be the cusps of the Cycloid, and the chain is in contact with the portion LBM of the Cycloid whose plane is vertical.

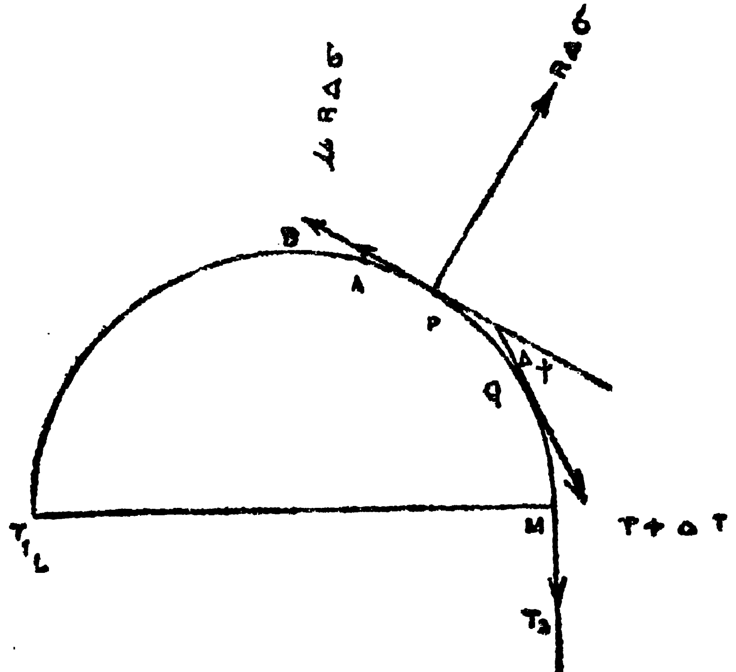
Let M be the linear density of the chain, which is supposed to be constant.

Let 'R' be the reaction per unit length between the pulley and the chain at the point P at any instant t.

Now $\rho = 4a\cos\psi$, where ρ is the radius of curvature at the point P.

Let T_1 be the tension at L, and T_2 the tension at M.

Let T be the tension at P.



Resolving along the tangent at P, and neglecting small quantities of the 2nd order we have:—

$$(T+\Delta T)\cos\Delta\psi - T + mg.\ \Delta\sigma\sin\psi - \mu R.\ \Delta\sigma = m.\Delta\sigma.\ \dot{v}$$

or $\Delta T + mg.\ \Delta\sigma\sin\psi - \mu\ R.\ \Delta\sigma = m\dot{v}.\ \Delta\sigma$

Dividing by $\Delta\sigma$ and then proceeding to limit we get

$$\frac{dT}{d\sigma} + mg\sin\psi - \mu R = m\dot{v} \quad ....(1)$$

Resolving along the inward normal at P, and neglecting small quantities of the 2nd order we have:—

$$(T+\Delta T)\sin\Delta\psi + mg.\ \Delta\sigma.\cos\psi - R.\ \Delta\sigma = \frac{mv^2}{\rho}\Delta\sigma$$

or $$T.\Delta\psi + mg\cos\psi.\ \Delta\sigma - R.\ \Delta\sigma = \frac{mv^2}{\rho}.\ \Delta\sigma$$

Dividing by $\Delta\sigma$ and proceeding to limit we have:—

$$\frac{T}{\rho} + mg\cos\psi - R = \frac{mv^2}{\rho} \quad ....(2)$$

From equation (1) and (2) eliminating R we get:—

$$\left(\frac{dT}{d\sigma} - \frac{\mu T}{\rho}\right) + mg(\sin\psi - \mu\cos\psi)$$

$$= m\dot{v} - \mu\frac{mv^2}{\rho}$$

or $$\rho\frac{dT}{d\sigma} - \mu T + mg\rho(\sin\psi - \mu\cos\psi)$$

$$= m\rho\dot{v} - \mu mv^2$$

or $$\frac{dT}{d\psi} - \mu T = m\rho\dot{v} + mg\rho(\mu\cos\psi - \sin\psi) - \mu mv^2$$

Substituting for $\rho = 4a\cos\psi$, we have

$$\frac{dT}{d\psi} - \mu T = 4am\dot{v}\cos\psi - \mu mv^2 + 4amg(\mu\cos^2\psi - \sin\psi\cos\psi).$$

Let us now get the tension at the point P.

$$\Big[Te^{-\mu\psi}\Big]_{-\frac{\pi}{2}}^{\psi} = 4am\dot{v}\int_{-\frac{\pi}{2}}^{\psi} e^{-\mu\psi}\cos\psi\,d\psi - \mu mv^2\int_{-\frac{\pi}{2}}^{\psi} e^{-\mu\psi}\,d\psi$$

$$+4amg\mu\int_{-\frac{\pi}{2}}^{\psi} e^{-\mu\psi}\cos^2\psi\,d\psi - 2amg\int_{-\frac{\pi}{2}}^{\psi} e^{-\mu\psi}\sin 2\psi\,d\psi$$

$$= 4\,amr \left[e^{-\mu\psi} \frac{(-\mu \cos\psi + \sin\psi)}{1+\mu^2} \right]_{-\frac{\pi}{2}}^{\psi} + mr^2 \left[e^{\mu\psi} \right]_{-\frac{\pi}{2}}^{\psi}$$

$$+2\,mga\mu \left[e^{-\mu\psi} \frac{(-\mu \cos 2\psi + 2 \sin 2\psi)}{\mu^2+4} \right]_{-\frac{\pi}{2}}^{\psi}$$

$$-2\,amg \left[e^{\mu\psi} \right]_{-\frac{\pi}{2}}^{\psi} + 2\,amg \left[e^{-\mu\psi} \frac{(\mu \sin 2\psi + 2 \cos 2\psi)}{\mu^2+4} \right]_{-\frac{\pi}{2}}^{\psi}$$

$$\therefore \quad T\, \bar{e}^{\mu\psi}$$

$$= T_1 e^{\frac{\mu\pi}{2}} + \frac{4\,amr}{1+\mu^2} \left[e^{-\mu\psi} (-\mu \cos\psi + \sin\psi) + e^{\frac{\mu\pi}{2}} \right]$$

$$+ mr^2 \left[\bar{e}^{\mu\psi} - e^{\mu\frac{\pi}{2}} \right] + \frac{2\,amg\mu}{\mu^2+4} \left[\bar{e}^{\mu\psi} (-\mu \cos 2\psi + 2 \sin 2\psi) - \mu\, e^{\mu\frac{\pi}{2}} \right]$$

$$-2\,amg \left[\bar{e}^{\mu\psi} - e^{\mu\frac{\pi}{2}} \right] + \frac{2\,amg}{\mu^2+4} \left[e^{-\mu\psi} (\mu \sin 2\psi + 2 \cos 2\psi) + 2 e^{\mu\frac{\pi}{2}} \right]$$

$$\text{Or } T = T_1\, e^{\mu(\psi+\frac{\pi}{2})} + \frac{4\,amr}{1+\mu^2} \left[(\sin\psi - \mu \cos\psi) + e^{\mu(\psi+\frac{\pi}{2})} \right]$$

$$+ mr^2 \left[1 - e^{\mu(\psi+\frac{\pi}{2})} \right] + \frac{2\,amg\mu}{\mu^2+4} \left[2 (\sin 2\psi - \mu \cos 2\psi) - \mu e^{(\psi+\frac{\pi}{2})} \right]$$

$$- 2\,amg \left[1 - e^{\mu(\psi+\frac{\pi}{2})} \right] + \frac{2\,amg}{\mu^2+4} \left[\mu \sin 2\psi + 2 \cos 2\psi) + 2\, e^{\mu(\psi+\frac{\pi}{2})} \right]$$

$$= \left[T_1 + \frac{4\,am\dot{v}}{1+\mu^2} - mv^2 - 2\,amg\,\frac{(\mu^2-2)}{(\mu^2+4)} + 2\,amg\right] \times e^{\mu\left(\psi+\frac{\pi}{2}\right)}$$

$$+ \frac{4\,am\dot{v}}{1+\mu^2}\sin\psi - \frac{4\,am\dot{v}\,\mu\cos\psi}{1+\mu^2} + mv^2 - 2\,amg$$

$$+ \frac{6\,amg\,\mu}{\mu^2+4}\sin 2\psi + \frac{2\,amg}{\mu^2+4}(2-\mu^2)\cos 2\psi$$

$$= \left[T_1 + \frac{4\,am\dot{v}}{1+\mu^2} - mv^2 + \frac{12\,amg}{\mu^2+4}\right]e^{\mu\left(\psi+\frac{\pi}{2}\right)}$$

$$+ \frac{4\,am\dot{v}}{1+\mu^2}\sin\psi - \frac{4\,am\dot{v}\,\mu\cos\psi}{1+\mu^2} + mv^2 - 2\,amg$$

$$+ \frac{6\,amg\mu}{\mu^2+4}\sin 2\psi + 2\,amg\,\frac{2-\mu^2}{\mu^2+4}\cos 2\psi\,.$$

When $\psi = \frac{\pi}{2}$ we get the tension T_2 at M.

$$\therefore\ T_2 = \left(T_1 + \frac{4\,am\dot{v}}{1+\mu^2} - mv^2 + \frac{12amg}{\mu^2+4}\right)e^{\mu\pi} + \frac{4\,am\dot{v}}{1+\mu^2}$$

$$+ mv^2 - \frac{12amg}{\mu^2+4}$$

$$= T_1 e^{\mu\pi} + \frac{4am\dot{v}}{1+\mu^2}\left(e^{\mu\pi}+1\right) - mv^2\left(e^{\mu\pi}-1\right)$$

$$+ \frac{12amg}{\mu^2+4}\left(e^{\mu\pi}-1\right).$$

When μ is small so that μ^2 etc. can be neglected,

$$T_2 = T_1(1+\mu\pi) + 4am\dot{v}(2+\mu\pi) - \mu mv^2\pi + 3\mu amg\pi.$$

When $\mu \longrightarrow 0$

$$T_2 \longrightarrow [T_1 + 8am\dot{v}]$$

$$\therefore\quad T_2 - T_1 = 8\,am\dot{v}$$

$= \dot{v} \times$ [mass of the chain lying on the perimeter of the Cycloid], as in the case of the circular pulley.

Let us now examine different cases.

(*a*) When $m \longrightarrow o$

$$T_2 \longrightarrow T_1 e^{\mu\pi}$$

(So that the ordinary formula in the case of light strings holds good even when the string is in motion.)

When μ is small so that μ^2 etc., can be neglected

$$T_2 \longrightarrow T_1 (1+\mu\pi)$$

(*b*) When $a \longrightarrow o$

$$T_2 \longrightarrow T_1 e^{\mu\pi} - mv^2 \left(e^{\mu\pi} - 1\right)$$

$$= \left(T_1 - mv^2\right) e^{\mu\pi} + mv^2$$, same as in the case of a circular pulley.

When μ is small

$$T_2 \longrightarrow T_1 (1+\mu\pi) - mv^2 \mu\pi$$

(*c*) When $v=o$ but $\dot{v} \neq o$ *i.e.* just at the instant when the motion begins

$$T_2 = T_1 e^{\mu\pi} + \frac{4am\dot{v}}{1+\mu^2}(e^{\mu\pi}+1) + \frac{12amg}{\mu^2+4}(e^{\mu\pi}-1)$$

(*d*) When $\dot{v}=o$ but $v \neq o$ *i.e.* when the chain is moving with uniform velocity

$$T_2 = T_1 e^{\mu\pi} - mv^2 (e^{\mu\pi}-1) + \frac{12amg}{\mu^2+4}(e^{\mu\pi}-1)$$

$\therefore T_2$ will be equal to $T_1 e^{\mu\pi}$, if

$$v = \sqrt{\frac{12\,ag}{\mu^2+4}}$$

If μ is so small that μ^2 etc. can be neglected $v = \sqrt{3ag}$.

So in the case of a heavy chain moving over a *slightly rough* Cycloidal pulley of finite dimensions, tension

at one end is $e^{\mu\pi}$ times the tension at the other end provided the chain is moving with a uniform velocity equal to $\sqrt{3ag}$.

Let us now calculate the total vertical pressure between the chain and the pulley.

Vertical pressure

$$= F = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} R\ (\cos\psi + \mu \sin\psi) d\rho$$

$$= \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} R\rho\ (\cos\psi + \mu \sin\psi) d\psi$$

But $R\rho = T + mg\rho\cos\psi - mv^2$ from (2)

$$\therefore F = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} (T - mv^2 + mg\rho\cos\psi)(\cos\psi + \mu\sin\psi)\, d\psi$$

$$= \sqrt{1+\mu^2} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} (T - mv^2 + 4\, amg \cos^2\psi) \cos(\psi - \theta)\, d\psi,$$

where $\theta = \tan^{-1}\mu$

Now $T - mv^2 + 4\, amg\cos^2\psi$

$$= \left(T_1 + \frac{4\, am\dot{v}}{1+\mu^2} - mv^2 + \frac{12\, amg}{\mu^2+4} \right) e^{\mu\left(\psi + \frac{\pi}{2}\right)} + \frac{4\, am\dot{v}}{1+\mu^2} \sin\psi$$

$$- \frac{4\, am\dot{v}.\ \mu \cos\psi}{1+\mu^2} + \frac{6\, amg\ \mu}{\mu^2+4} \sin 2\psi$$

$$+ 2\, amg.\ \frac{2-\mu^2}{\mu^2+4} \cos 2\psi + 2\, amg \cos 2\psi$$

$$= \left(T_1 + \frac{4\, am\dot{v}}{1+\mu^2} - mv^2 + \frac{12\, amg}{\mu^2+4} \right) e^{\mu\left(\psi + \frac{\pi}{2}\right)}$$

$$+ \frac{4\, am\dot{v}}{1+\mu^2} \sin\psi - \frac{4\, am\dot{v}\ \mu\cos\psi}{1+\mu^2} + \frac{6\, amg\mu}{\mu^2+4} \sin 2\psi$$

$$+ \frac{12\, amg}{\mu^2+4} \cos 2\psi$$

$$=A\, e^{|\mu}\left(\psi+\frac{\pi}{2}+B\sqrt{1+\mu^2}\, sin\,(\psi-\theta)+\frac{6\, amg\mu}{\mu^2+4}\, sin\ 2\,\psi\right.$$

$$\left.+\ \frac{12\, amg}{\mu^2+4}\, cos\ 2\psi\right.,$$

where $A = T_1 + \dfrac{4\, am\dot{v}}{1+\mu^2} - mv^2 + \dfrac{12\, amg}{\mu^2+4}$

$B = \dfrac{4\, am\dot{v}}{1+\mu^2}$

$$\therefore F = A\sqrt{1+\mu^2}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} e^{\mu\left(\psi+\frac{\pi}{2}\right)} cos\ (\psi-\theta) d\psi$$

$$+\frac{B}{2}(1+\mu^2)\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} sin\ 2\,(\psi-\theta)\, d\psi$$

$$+\ \frac{\sqrt{1+\mu^2}}{\mu^2+4}\, 6\, amg\mu \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} sin\ 2\psi\ cos\ (\psi-\theta)\ d\psi$$

$$+\ \frac{\sqrt{1+\mu^2}}{\mu^2+4}\, 12\, amg \int_{-\pi}^{\frac{\pi}{2}} cos\ 2\psi\ cos\ (\psi-\theta)\ d\psi$$

$$=A\sqrt{1+\mu^2}\, e^{\frac{\mu\pi}{2}}\left[e^{\mu\psi}\left\{\frac{\mu\, cos\,(\psi-\theta)+sin\,(\psi-\theta)}{1+\mu^2}\right\}\right]$$

$$-\ \frac{B}{4}(1+\mu^2)\Big[cos\ 2\,(\psi-\theta)\Big]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$-\ \frac{3\, amg\,\mu\,\sqrt{1+\mu^2}}{\mu^2+4}\left[\frac{cos\ (3\psi-\theta)}{3}+cos\ (\psi-\theta)\right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$+\ \frac{6\, amg\,\sqrt{\mu^2+1}}{\mu^2+4}\left[\frac{sin\ (3\psi-\theta)}{3}+sin\ (\psi+\theta)\right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$= A\left(e^{\mu\pi}+1\right) - \frac{B}{4}(1+\mu^2)\left[\cos(\pi-2\theta)-\cos(\pi+2\theta)\right]$$

$$-\frac{3amg\ \mu\sqrt{1+\mu^2}}{\mu^2+4}\left[\frac{\cos\left(\frac{3\pi}{2}-\theta\right)-\cos\left(\frac{3\pi}{2}+\theta\right)}{3}+\right.$$

$$\left.\cos\left(\frac{\pi}{2}+\theta\right)-\cos\left(\frac{\pi}{2}-\theta\right)\right]$$

$$+6\,amg\frac{\sqrt{\mu^2+1}}{\mu^2+4}\left[\frac{\sin\left(\frac{\pi}{2}-\theta\right)+\sin\left(\frac{3\pi}{2}+\theta\right)}{3}+\right.$$

$$\left.\sin\left(\frac{\pi}{2}+\theta\right)+\sin\left(\frac{\pi}{2}-\theta\right)\right]$$

$$= A\left(e^{\mu\pi}+1\right)+8\,amg.\frac{\mu^2+1}{\mu^2+4}$$

$$=\left(T_1+\frac{4\,am\dot{v}}{1+\mu^2}-mv^2+\frac{12\,amg}{\mu^2+4}\right)\left(e^{\mu\pi}+1\right)$$

$$+8\,amg.\ \frac{\mu^2+1}{\mu^2+4}$$

Approximations :—

(*i*) If μ is small so that μ^2 etc., can be neglected

$$F=\left(T_1+4\,am\dot{v}-mv^2+3\,amg\right)(2+\mu\pi)+2\,amg.$$

(*ii*) If $\mu\longrightarrow o$ so that the pulley is smooth

$$F\longrightarrow 2\,T_1+8ma\dot{v}-2mv^2+8\,amg\,]$$

Let us now examine different cases

(*a*) When $m\longrightarrow o$ *i. e.*, the chain is light

$$F\longrightarrow T_1\left(e^{\mu\pi}+1\right)=T_2+T_1\quad\left[\because T_2=T_1\,e^{\mu\pi}\right]$$

When μ is small

$$F\longrightarrow T_1\left(2+\mu\pi\right)$$

(*b*) When $a \longrightarrow o$, *i.e.*, the pulley is small

$$F = \left(T_1 - mv^2\right)\left(e^{\mu\pi} + 1\right)$$

If μ is small

$$F = \left(T_1 - mv^2\right)\left(2 + \mu\pi\right)$$

If $\mu \longrightarrow o$

$$F = 2\left(T_1 - mv^2\right)$$

(*c*) When $v = o$ but $\dot{v} \neq o$ *i. e.*, just at the instant when the motion begins.

If μ_1, the limiting friction in this case $(< \mu)$, be very small.

$$F \longrightarrow (T_1 + 4\, am\dot{v} + 3\, amg)\,(2 + \mu_1\pi) + 2\, amg$$

When $\mu_1 \longrightarrow o$

$$F \longrightarrow 2\,(T_1 + 4\, am\dot{v} + 4\, amg)$$

(*d*) When $\dot{v} = o$ but $v \neq o$ *i. e.*, the chain is moving with constant velocity,

Also μ is small.

$$F \longrightarrow (T_1 - mv^2 + 3\, amg)\,(2 + \mu\pi) + 2\, amg$$

When $\mu \longrightarrow o$

$$F = 2\,(T_1 - mv^2) + 8\, amg$$

(*e*) When $\dot{v} = o$ also $v = o$

also μ is small

$$F \longrightarrow (T_1 + 3\, amg)\,(2 + \mu\pi) + 2\, amg$$

When $\mu \longrightarrow o$

$$F \longrightarrow 2\, T_1 + 8\, amg$$

Now in general let us find out when the total vertical thrust vanishes, assuming the pulley to be rough and of finite dimensions.

Consider the equation of motion of the portion MN $(=x)$ of the string

$$M x v \frac{dv}{dx} = mgx - T_2$$

$$= mgx - T_1 e^{\mu\pi} - \frac{4am\dot{v}}{1+\mu^2}\left(e^{\mu\pi}+1\right)$$

$$+ mv^2\left(e^{\mu\pi}-1\right) - \frac{12amg}{\mu^2+4}\left(e^{\mu\pi}-1\right)$$

$$\therefore\ T_1 e^{\mu\pi} = mgx - mxv\frac{dv}{dx} - \frac{4am\dot{v}}{1+\mu^2}\left(e^{\mu\pi}+1\right)$$

$$+ mv^2\left(e^{\mu\pi}-1\right) - \frac{12amg}{\mu^2+4}\left(e^{\mu\pi}-1\right)$$

Now F vanishes when ....(3)

$$\left(T_1 + \frac{4am\dot{v}}{1+\mu^2} - mv^2 + \frac{12amg}{\mu^2+4}\right)\left(e^{\mu\pi}+1\right)$$

$$+ 8amg\cdot\frac{1+\mu^2}{\mu^2+4} = 0$$

i.e. when

$$T_1 e^{\mu\pi} = \left(mv^2 - \frac{4am\dot{v}}{1+\mu^2} - \frac{12amg}{\mu^2+4}\right)e^{\mu\pi}$$

$$+ 8amg\frac{\mu^2+1}{\mu^2+4}\cdot\frac{e^{\mu\pi}}{1+e^{\mu\pi}}$$

From equation (3) we have

$$mgx - mxv\frac{dv}{dx} - \frac{4am\dot{v}}{1+\mu^2}\left(e^{\mu\pi}+1\right) + mv^2\left(e^{\mu\pi}-1\right)$$

$$-\frac{12amg}{\mu^2+4}\left(e^{\mu\pi}-1\right) = \left(mv^2 - \frac{4am\dot{v}}{1+\mu^2} - \frac{12amg}{\mu^2+4}\right)e^{\mu\pi}$$

$$+ 8amg\frac{\mu^2+1}{\mu^2+4}\frac{e^{\mu\pi}}{e^{\mu\pi}+1}$$

$$v\frac{dv}{dx}\left[x + \frac{4a\left(e^{\mu}+1\right)}{1+\mu^2} - \frac{4a e^{\mu\pi}}{1+\mu^2}\right] + v^2\left(e^{\mu\pi} - e^{\mu\pi}+1\right)$$

$$= gx - \frac{12ag}{\mu^2+4}\left(e^{\mu\pi} - 1\right) + \frac{12ag}{\mu^2+4} e^{\mu\pi}$$

$$- \frac{8ag\,(1+\mu^2)\, e^{\mu\pi}}{(\mu^2+4)\,(1+e^{\mu\pi})}$$

$$\frac{dv}{dx}\left[x + \frac{4a}{1+\mu^2}\right] + v^2 = gx + \frac{12ag}{\mu^2+4} - \frac{8ag\,(1+\mu^2)e^{\mu\pi}}{(\mu^2+4)\,(1+e^{\mu\pi})}$$

$$= gx + \frac{4ag}{\mu^2+4}\left[3 - \frac{2\,(1+\mu^2)e^{\mu\pi}}{1+e^{\mu\pi}}\right]$$

$$= gx + \frac{4ag}{\mu^2+4}\left[\frac{3 + e^{\mu\pi}(1-2\mu^2)}{1+e^{\mu\pi}}\right]$$

Now put $\frac{4a}{1+\mu^2} = p$, and

$$\frac{4a}{\mu^2+4}\left[\frac{3+e^{\mu\pi}\,(1-2\mu^2)}{1+e^{\mu\pi}}\right] = k$$

We get

$$v\frac{dv}{dx}\,(x + p) + v^2 = g\,(x+k)$$

Put $\quad x+p = z$

Then $\quad x+k = z-p+k$

We have

$$v\,z\,\frac{dv}{dz} + v^2 = gz - g\,(p-k)$$

Multiplying by $2z$ and integrating, we get

$$v^2z^2 = \frac{2g}{3}z^3 - g\,(p-k)\,z^2 + \text{const.}$$

If p > 3k

Then if we have the initial condition that $v=0$ when $z=\frac{3}{2}(p-k)$ or $x=\frac{p-3k}{2}$ then the constant is zero

We get $v^2z^2 = \frac{2}{3}\,gz^3 - g\,(p-k)\,z^2$

or $v^2 = \frac{2}{3}\,gz - g\,(p-k)$

Differentiating with respect to z again we get

$$2\ v\frac{dv}{dz}=\tfrac{2}{3}\ g$$

$$\text{or}\quad v\frac{dv}{dz}=\tfrac{1}{3}\ g$$

$$\therefore\quad \frac{dv}{dt}=\tfrac{1}{3}\ g$$

If $p<3\,k$

We can take as our initial conditions that $v=\sqrt{\frac{g}{3}(3k-p)}$ when $z=p$ or $k=o$ and the constant would be zero and we get as before

$$\frac{dv}{dt}=\tfrac{1}{3}\ g$$

If $p>3k$, then in the case of a large rough Cycloidal pulley, the vertical thrust between the pulley and the chain will vanish if the chain moves with acceleration equal to $\frac{1}{3}g$, provided the chain starts from rest when the free end N is at a depth $\frac{p-3k}{2}$ below the centre of the pulley.

If $p<3k$, then in the case of a large rough pulley, the vertical thrust between the chain and the pulley will vanish if the chain moves with acceleration equal to one-third of gravity provided a velocity equal to $\sqrt{\frac{g\,(3k-p)}{3}}$ be imparted to the chain when the free end N is at M.

If $p=3k$, this imparted velocity becomes zero.

If μ be very small so that μ^2 etc. can be neglected, $p\longrightarrow 4a$ and $k\longrightarrow a2-\frac{\mu\pi a}{2}$. In this case the velocity imparted becomes equal to $\sqrt{ga\left(\frac{2}{3}-\frac{\mu\pi}{2}\right)}$ and is positive when μ is small.

Now let us consider the case in which a weight equal to that of the length l of the chain is attached to a free end N.

The equation of motion becomes

$$m\ (x+l)\ \frac{dv}{dx}=mg\ (x+l)-T_2,\ \text{and}$$

as before we get

$$zv\ \frac{dv}{dz}+v^2=gz-g\ (p-k)\ \text{where}\ z=x+l+p,\ \text{and}$$

p and k have the same meaning as before

$$\therefore\quad v^2z^2=\frac{2g}{3}\ z^3-g\ (p-k)\ z^2+\text{const.}$$

If $p>\ 3k+2l$

Then if we have the initial condition that $v=o$ when

$$z=\tfrac{3}{2}\ (p-k)\text{or}\ x=\frac{p-3k-2l}{2}$$

then the constant is zero.

$$\text{We get}\quad v^2z^2=\frac{2g}{3}z^3-g\ (p-k)\ z$$

$$\text{or}\ v^2\ =\frac{2g}{3}z-g\ (p-k)$$

Differentiating with respect to z ag

$$2\ v\ \frac{dv}{dz}=\frac{2\ g}{3}$$

$$\therefore\ v\ \frac{dv}{dz}=\ \frac{g}{3}$$

$$\text{or}\ \frac{dv}{dt}=\tfrac{1}{3}\,g$$

If $p\ <\ 3k+2l,$

We can take as our initial conditions that $v=\sqrt{\frac{g}{3}\ (3k+2l-p)}$ when $z=p+l$ or $x=o$ and the constant would be zero and we get as before

$$\frac{dv}{dt}=\tfrac{1}{3}\,g$$

So, if $p>\ 3\ k+2\ l$, then in the case of a large rough Cycloidal pulley the vertical thrust between the chain, to which a weight equal to that of length l is attached to

the free end N, and the pulley will vanish if the chain moves with acceleration equal to $\frac{1}{3}g$, provded the chain starts from rest when the free end N is at a depth $\frac{p-3k-2l}{2}$ below the centre of the pulley.

If $p < 3k+2l$ then in the case of a large rough Cycloidal pulley the vertical thrust between it and the chain to which a weight equal to that of length l is attached to the free end N will vanish if the chain moves with acceleration equal to one-third of gravity provided a velocity equal to $\sqrt{\frac{g}{3}(3k+2l-p)}$ be imparted to the chain when the free end N is at M.

If $p=3k+2l$ this imparted velocity becomes zero.

Let us now calculate the total horizontal thrust between the chain and the pulley.

The horizontal thrust

$$H = \int_{-\pi}^{\frac{\pi}{2}} (R.\ \Delta\sigma\ sin\psi - \mu R.\ \Delta\sigma\ cos\psi)$$

$$= \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} R.\ \Delta\sigma\ (sin\psi - \mu\ cos\psi)$$

$$= \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} R\rho\ (sin\psi - \mu\ cos\psi)\ d\psi$$

$$= \sqrt{1+\mu^2} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} R\rho\ sin\ (\psi-\theta)\ d\psi$$

But $R\rho = A\ e^{\mu\left(\psi+\frac{\pi}{2}\right)} + B\sqrt{1+\mu^2}\ sin\ (\psi-\theta)$

$$+ \frac{6\ amg\ \mu}{\mu^2+4} sin\ 2\psi + \frac{12\ amg}{\mu^2+4}\ cos\ 2\psi$$

$$H = A\sqrt{1+\mu^2}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} e^{\mu\left(\psi+\frac{\pi}{2}\right)} \sin(\psi-\theta)\, d\psi$$

$$+ \frac{B}{2}(1+\mu^2)\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \sin^2(\psi-\theta)\, d\psi$$

$$+ \frac{6\, amg\mu\sqrt{1+\mu^2}}{\mu^2+4}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \sin 2\psi \sin(\psi-\theta)\, d\psi$$

$$+ \sqrt{1+\mu^2}\,\frac{12\, amg\mu}{\mu^2+4}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \cos 2\psi \sin(\psi-\theta)\, d\psi$$

$$= A\sqrt{1+\mu^2}\, e^{\frac{\mu\pi}{2}}\left[e^{\mu\psi}\left\{\mu \sin(\psi-\theta)-\cos(\psi-\theta)\right\}\right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$+ \frac{B}{2}(1+\mu^2)\left[\psi-\tfrac{1}{2}\sin 2(\psi-\theta)\right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$+ \frac{3\, amg\mu\sqrt{1+\mu^2}}{\mu^2+4}\left[\sin(\psi+\theta)\right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$- \frac{amg\mu\sqrt{1+\mu^2}}{\mu^2+4}\left[\sin(3\psi-\theta)\right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$- \frac{2\, amg\sqrt{1+\mu^2}}{\mu^2+4}\left[\cos(3\psi-\theta)\right]$$

$$+ \frac{6\, amg \sqrt{1+\mu^2}}{\mu^2+4} \Big[\cos.\ (\psi + \theta)\Big]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$= A\, e^{\frac{\mu\pi}{2}} \frac{\sqrt{1+\mu^2}}{1+\mu^2} \left(e^{\frac{\mu\pi}{2}} + e^{\frac{-\mu\pi}{2}}\right) \left(\mu \cos\theta - \sin\theta\right)$$

$$+ \frac{B}{2} \left(1+\mu^2\right) \pi + \frac{6\, amg\mu \sqrt{1+\mu^2}}{\mu^2+4} \cos\theta + \frac{2\, amg\mu \sqrt{1+\mu^2} \cos\theta}{\mu^2+4}$$

$$+ \frac{4\, amg \sqrt{1+\mu^2}}{\mu^2+4} \sin\theta - \frac{12\, amg \sqrt{1+\mu^2}}{\mu^2+4} \sin\theta$$

$$= \frac{A \sqrt{1+\mu^2}}{1+\mu^2} \left(1 + e^{\mu\pi}\right) \left(\mu \cos\theta - \sin\theta\right) + \frac{B}{2}\, \pi\, \sqrt{1+\mu^2}$$

$$+ \frac{8\, amg \sqrt{1+\mu^2}}{\mu^2+4} \left(\mu \cos\theta - \sin\theta\right)$$

$= 2ma\pi\dot{v}$, substituting for θ and B.

It is interesting to note that the horizontal thrust does not explicitly depend on friction, and it is equal to a force which would produce the same acceleration $\dot{v}$ on a mass of the chain equal to that of the horizontal projection, of the projection LBM of the chain.

Let us consider the different cases.

(*i*) When $\dot{v} = o$

$$H = 0$$

i. e. when the motion is uniform the horizontal thrust vanishes.

(*ii*) When $m \longrightarrow o$

$$H \longrightarrow o$$

(*iii*) When $a \longrightarrow o$

$$H \longrightarrow o$$

DEPARTMENT OF LAW

THE CONCEPTION OF MUSLIM MARRIAGE

BY

MAHOMED U. S. JUNG, B.A., LL.B., (CANTAB.), Bar-at-Law.

READER IN LAW

The Muslim jurists have not attempted a precise definition of marriage, they speak about the regulation of the marriage-tie, about its continuance and dissolution.

Baillie takes his definition from the Kanz, and the Kifayah—"Marriage is a contract which has for its design or object the right of enjoyment, and the procreation of children."[1]

Sir Roland Wilson defines it thus:—"Marriage is a contract for the purpose of legalising sexual intercourse and the procreation of children."[2]

Marriage in its origin is "a contract of natural law" and though entirely a personal consensual contract, it is not merely a civil contract under the Muslim law. The institution of marriage is regarded by our jurists as a secular contract partaking of the nature of Ibadat (religious rite)[3]; for the procreation of children, the regulation of social life and for the benefit of society. Islam considers marriage also as a religious devotion. The author of the Darrul Mukhtar observes:

[1] Digest p. 4.

[2] Anglo-Muhammadan Law p. 94.

[3] Story's 'Conflict of Laws' p. 143. "In many civilised countries...it has had the sanctions of religion superadded. It then becomes a religious, as well as a natural and civil, contract; for it is a great mistake to suppose that because it is the one, therefore it may not likewise be the other."

"There is no devotion for us which has all along been recognised from the time of Adam up to the present time, and will continue even in paradise except marriage and faith."

درالمختار
ليس لنا عبادة شرعت من عهد آدم
عليه السلام الي الان ثم تستمر في الجنة
الا النكاح والايمان -

The Prophet of God himself declared;

"Marriage is my Sunnat, and those who do not obey it are not my followers."

كفايه
يقول عليه السلام النكاح من سنتي
فمن رغب عن سنتي فليس مني -

A famous Hadis is reported in Muslim

"A woman is married owing to four qualifications, for her property or nobility of pedigree or beauty, or on account of piety. Ye should marry for piety."

مسلم
تنكح المراة لاربع لمالها لحسبها
ولجمالها ولدينها فاظفر بذات الدين -

According to the Kifayah, marriage has been given preference over jehad (religious war), which is a cardinal duty of religion. Faith which is the root of all divine worship is classified under the same category as marriage.

Marriage is regarded by all the jurists, as "Sunnat Muvakida"; that is, an institution the compliance with which is considered as virtuous and a deviation from which is regarded as a sin. Sunnat Muvakida is thus defined.—"The person who complies with it is rewarded in the next world, and he who does not sins." Hence marriage is a religious rite under the Muslim law, although it is in the form of a secular transaction and a civil contract. The notion of contract is brought into prominence, because it it renders facility of divorce, and allows separation of parties easily in the eye of the law, whereas the sacramental aspect would make the marriage-tie indissoluble.

In the celebrated book Tandih, Marriage is described as an institution which has been legalised for manifold objects, "such as preservation of the species, the fixing

of descent, restraining men from debauchery, the encouragement of chastity, promotion of love and union between the husband and wife, and of mutual help in earning livelihood."

Islam provides ample provisions for the repudiation and cancellation of marriage[1]. It grants to the husband the supreme power of divorce at will: but it allows the wife to contract at the time of the marriage, or thereafter to delegate the power of divorce to a third person, or reserve it to herself. This is technically known as the doctrine of Thafveez-ul-Tulak (تفويض الطلاق); while other forms of repudiations effected by mutual agreement and on payment of compensation are known, as "mubarat" and "khula" respectively. The abuse or recklessness with which the right of divorce may be exercised by the husband is restricted by threats of divine displeasure.

The Prophet commanded:

"God has not created anything upon the face of this earth which he dislikes more than divorce."

الدارقطنی
ولاخلق الله شیا علی وجه
الارض ابغض الیه من الطلاق-

Howerver the Holy Koran itself sanctioned divorce, as a legitimate mode of separation in extreme cases of unhappiness and misery.

Part. II., ch. II.

"If they have resolved on a divorce, (then let them.) Allah is Hearing and Knowing".

وان عزموا الطلاق فان الله
سمیع علیم

[1]Ameer Ali, Mahommedan Law. Vol. II. p. 510. "At the time of the Prophet's appearance, the Hillelite doctrines were chiefly in force among the Jewish tribes of Arabia, and repudiations by the husbands were as common among them as among the pagan Arabs." The restrictions imposed by the Shammaites on divorce were not upheld by the school of Hillel.

The Roman law of marriage furnishes a unique parallel. At Rome, marriage was regarded as a religious communion between husband and wife. Modestinus in his celebrated definition observed: "Nuptiae sunt coniunctio maris et feminae, et consortium omnis, vitae divini et humani juris communicatio." (Dig. 23. 2. 1.)

Modestinus' words re-echo the reminiscence of the primitive practice, as by the time of the Emperor Justinian the notion of contractual relation had gained predominance, and the Institutes defined marriage thus.

Lib. I. Tit. 9. 1.

"Marriage, or matrimony, is the union of a man and woman, carrying with it a mode of life in which they are inseparable."

Nuptiae autem sive matrimonium est viri et mulieris coniunctio, individuam consuetudinem vitae continens.

Under the Roman law persons who were married by confarreatio originally could not be divorced at all and according to Gaius a woman in manus could not divorce herself from her husband, but after repudiation could compel him to release her.

Gaius. I. 137.

"A wife subject to manus can no more compel her husband to release her therefrom without dissolution of the marriage than a daughter can compel her father to emancipate her."

........*haec autem virum suum*[1] nihilomagis potest cogere, quam et filia patrem. Sed filia quidem nullo modo patrem potest cogere, etiamsi adoptiva sit: haec autem *virum* repudio missoproinde compellere potest.

Later on by the time of Domitian the marriage by confarrertio was allowed to be disolved by a religious form of divorce called "diffarreatio," and the Lex Julia de

[1]Ex. Coni. Kruegeri et Huschkii.

adulteriis[1] also provided a special form of divorce in the presence of seven witnesses.

The gifted intelligence of the Roman jurists settled the conflict, and the popular view was soon upheld, that the essence of marriage lay in the "maritalis affectio," and therefore the continuance of marriage depended upon the continuance of the "affectio;" henceforth the marriage was permitted to be dissolved at the option of either party. If the marriage was cancelled by mutual agreement it was called divortium and resembles the "mubarat" form of repudiation of the Muslim law, and if by the act of one party the Romans called such a divorce repudium, and it is like the "khula" divorce of the Muslim law.

Sir Henry Maine says that the Roman marriage was "the laxest the western world has seen". Indeed with the freedom of marriage and divorce practically at will, it was so. Later Christianity endeavoured to make a change. The conception of indissolubility of marriage began to operate, and eventually in the eighth century it transformed marriage into a simple sacrament: and in the reign of Leo III, the Isaurian, an ecclesiastical benediction was made essential to a valid solemnization of marriage.[2] But for a long time although the marriage ceremony was a religious one it continued to be treated as a civil contract. Christianity maintained that marriage was a sacrament. The man and wife were made "one flesh" by the act of God. "What therefore God hath joined together let no man put asunder;" "quod Deus conjunxit, homo non separet."

[1] B. C. 17 (Dig. 24. 2. 9.)

[2] Professor Holland (Jurisprudence, p. 295) says—"The Christian Church, adopting from Roman law the maxim that 'consensus facit matrimonium' though it stigmatised such marriages as irregular, because not made in 'facie ecclesir'; nevertheless upheld them as valid till the Council of Trent declared all marriages to be void unless made in the presence of a priest and witnesses."

The Catholic Church while recognising the validity of private contracts. required the performance of a religious ceremony, so that the newly wedded parties were "sanctified by the word of God and prayer," and the parties to the marriage were themselves regarded as the 'ministers of the sacrament." Some have observed, "Matrimonii sacramentum non est, nisi quid contractui accessorium ab eoque separabile, ipsumque sacramentum in una tantum nuptiali bendictione situm est."[1] The notion that marriage was a sacred tie naturally made it indissoluble. For the separation of the parties the Canon law required the decree of nullity, "annullatio matrimonii," a judicial fiction that it is not the severing of the marriage tie, but a solemn affirmation that such marriage never existed at all.

The Hindu law treats marriage as a sacrament. It is a holy union and not a contract. It is a religious duty incumbent upon all Hindus. The sacred Hindu codes describe marriage as an important "sanskara", and it is declared, to be the last of the ten sanskaras necessary for the regeneration of males (of the twice-born classes) and for women and for the Sudras marriage is the only prescribed sanskara. The Hindu law adheres strictly to the sacramental aspect of the union of man and woman, and the indissolubility of the marriage tie is essential, consequently legal divorce is not known to the general Hindu law.

The laws of Manu provided none.

"Neither by sale nor by repudiation is a wife released from her husband; such we know the law to be, which the Lord of creatures (Prajapati) made of old."

न विक्रयविसर्गाभ्यां भर्तुर्भार्या विमुच्यते
एवं धर्मं विजानीमः प्राक् प्रजापतिनिर्मितम् ॥
(Some substitute "निष्क्रय" for "विक्रय"

[1]. The Encyclopædia Britannica, Vol. XVII, p. 755 (11th edition).

In Story's Conflict of Laws, we meet with this remarkable observation made by Lord Robertson.—"The contract of marriage is the most important of all human transactions. It is the very basis of the whole fabric of civilised society. The status of marriage is juris gentium, and the foundation of it, like that of all other contracts, rests on the consent of parties. But it differs from other contracts, in this, that the rights, obligations, or duties arising from it are not left entirely to be regulated by the agreements of parties, but are, to a certain extent, matters of municipal regulation, over which the parties have no control by any declaration of their will;......unlike other contracts, it cannot, in general amongst civilised nations, be dissolved by mutual consent, and it subsists in full force even although one of the parties should be for ever rendered incapable, as in the case of incurable insanity or the like, from performing his part of the mutual contract."[1]

Lord Robertson's view represents the matrimonial law of England of his time, and the principles which he has enunciated conflict with the Muslim law of marriage, inasmuch as divorce by mutual consent "mubarat" and also in "khula" form is permissible, and impotency if not within the knowledge of the wife, at the time of the marriage, makes the contract voidable, and separation can be effected by a judicial decree.

Further the conception of marriage, as "the voluntary union for life of one man and one woman to the exclusion of all others" is not applicable in Islam, for the Muslim law considers polygamy as lawful. Hence the Muslim ideas of matrimony are not in harmony with the Roman, Christian, or the Hindu conception of marriage. Islam differs from all in treating marriage, at the same

[1]Story's 'Conflict of Laws' p. 144.
[2]Per Lord Penzance in Hyde V. Hyde and Woodmansee, L. R. P. and M. 130.

time, as a devotion and a contract. It is a compromise between two divergent schools of thought, it falls short of the Roman conception of "free marriage", predicating the legal equality of the married pair in all respects; but it rises above the conception of indissolubility of a sacrament. Approximating to the Roman "free marriage" is the modern progressive conception of matrimony in the United States of America. The ancient view that husband and wife are one person (according to Blackstone this was the old English Common law rule also) is not found in the United States. It has been replaced by the Roman conception that married parties are two distinct persons. It is equally interesting that the Muslim law always acknowledged this view, and a Muslim woman has a definite independent legal status in the eye of the law. The notion of the wife's separate property and that there was no community of goods between husband and wife, is fully recognised by the Muslim law.

In fact, the contractual aspect of marriage is so prominent in the Muslim law that it has led some jurists to treat it entirely as a civil contract. Mr. Shama Charan Sircar, the Tagore law lecturer (1873) says, that "marriage among Muhammadans is not a sacrament, but purely a civil contract; and though it is solemnised generally with recitation of certain verses from the Koran, yet the Muhammadan law does not positively prescribe any service peculiar to the occasion." These observations were accepted by Mr. Justice Syed Mahmud in a judgment and he remarked, "According to Muhammadan law, marriage is a civil contract, upon the completion of which by proposal and acceptance, all the rights and obligations which it creates, arise immediately and simultaneously,"[1] and further he compared marriage and dower with the contract of sale

[1]. *8 All., 149.*

thus.—"Her right to resist her husband, so long as the dower remains unpaid, is analogous to the lien of a vendor upon the sold goods, while they remain in his possession and so long as the price or any part of it is unpaid, and her surrender to her husband resembles the delivery of the goods to the vendee........."[1]. His Lordship's remarks remind one of the ancient customs of marriage by purchase and sale—rather a backward step. Mr. Justice Abdur Rahim has correctly observed that "the Muhammadan jurists regard the institution of marriage as partaking both of the nature of 'Ibadat' or devotional acts and 'muamalat' or dealings among men"[2]. The intimate connection between religion and law, and even politics is so interwoven in the Muslim faith that it is difficult to draw defined and clear distinctions; the more so when marriage is regarded as the pillar of faith and Sunnat Muvakida by all the jurists.[3] The learned of the Sunni sect have in some cases considered marriage to be a duty, in others obligatory, while in some cases abominable and sinful.

It is customary and obligatory to recite the Surat-ul-Fateha (the opening chapter of Koran) at the time of the Nikah, and an omission is considered as unorthodox. Indeed these ceremonies are signs of solemnity, and as under Muhammadan law, an established custom is recognised as equivalent to law, it is incorrect to say that an omission to recite Koranic verses is of no legal significance; at least it raises a rebuttable presumption as to the validity of marriage.[4]

[1]. *Jurisprudence p. 327. It is similar to Modestinus' view "divini et humani juris" (Dig. 23. 2. 1.).*

[2]. *Morley's Digest Vol. 1 P. clxxxiii. "The laws of the Hindus and Muhammadans are part and parcel of their religion."*

[3]. *11 P. R. No. 124 Boulnois J. observed the "legal mode of establishing the status of marriage is connected with a religious ceremony." 13 A. L. J. 113. The Privy Council observed that a "Nikah marriage is a religious ceremony."*

Muslim marriage is thus an institution of "Ibadat" clothed in the legal form of contract, regulating sexual intercourse; but its continuance is dependent upon the maintenance of conjugal affection. It is only in extreme cases that a dissolution is effected in harmony with the dictates of the Prophet; it also partakes of the nature of partnership for economic ends and social co-operation for the benefit of uniformity and order in society.

DEPARTMENT OF CHEMISTRY.

NEGATIVE CATALYSIS IN OXIDATION REACTIONS.

N. R. DHAR.

Many examples of the phenomenon of negative catalysis in oxidation reactions are known from a long time. Thenard (Traite. de. Chim. *1* (1816) 236) first observed that the oxidation of phosphorus is retarded by the presence of certain organic vapours. Graham (Quarterly Journal of Science *11*, 1829, 83) was the first to observe that alcohol vapour, ether, ethylene, naphtha, turpentine, H_2S etc., protect phosphorus from being acted upon by oxygen. Several other workers notably Berthollet, Mitscherlich, Schonbein, Vant Hoff, (Zeit. Phys. Chem. *16*. (1895) 415) Centerszwer, (Zeit. Phys. Chem. *26* (1898) 1) Scharf (Zeit. Phys. Chem. *62*, (1908) 179) Thrope and Tutton (Jour. Chem. Soc. *57* (1890) 550) Weiser and Garrison (Jour. Phys. Chem. *25* 1921 61; 473) and others have observed that vapours of organic substances like alcohol, turpentine etc., markedly retard not only the oxidation of phosphorus by oxygen or air but the oxidation of phosphorus trioxide, is also retarded by vapours of organic substances. In other words alcohol, turpentine, H_2S and the vapour of other organic substances act as negative catalysts in the oxidation of phosphorus by air or oxygen.

Adrian (Jour. Pharm. Chem. (VI) *18* (1903) 5) observed that the presence of ethyl alcohol prevents the oxidation of chloroform by oxygen or air in light.

In the oxidation of Na_2SO_3 by oxygen or air many negative catalysts are known. The effect of negative catalysts on the oxidation of Na_2SO_3 was first studied by Bigelow (Zeit. Phys. Chem. *26* (1898) 493) who found

that the oxidation of the salt in aqueous solution was greatly retarded by the presence of minute quantity of benzaldehyde, isobutyl alcohol, glycerol, phenol, tartaric acid, mannitol, etc. Bigelow also demonstrated that the effect of a negative catalyst is not on the rate of solution of oxygen but on the rate of the reaction between the sulphite and oxygen. A few years later Titoff substantiated Bigelow's results and in addition studied the simultaneous effect produced by $CuSO_4$ a powerful accelerator and mannitol a strong retarder. He found that these two substances do not exert any additive effect but influence each other. Young (Jour. Amer. Chem. Soc. *23*, (1901) 119; *24*, (1902), 297) found that small quantities of certain alkaloids, like quinine, morphine, brucine, nicotine and substances like aniline hydroxide, amine, ammonium salts, KCN etc., also greatly retard this oxidation, specially if this solution is alkaline.

The inhebitary effect of sucrose, invert sugar, asparatic acid etc., had been observed by Sailland (Zeit. ver. Zuckerind *63*, (1913) 1035).

In 1912 we conducted some experiments on this line and the results were published in 1920 (Dhar, Dutta, Bhattacharya, Proc. K. Akad. Wetensch, Amsterdam *33*, 1920, 300). We determined the velocity of the oxidation of Na_2SO_3 in air in presence of various organic substances. We were quite surprised to find that the oxidation of Na_2SO_3 is markedly affected by the quality of water used. Ordinary distilled water was quite inefficient as it contained sufficient dissolved salts and gases to affect course of the reactions markedly. Consequently freshly prepared conductivity water was used in our experiments; in spite of every precaution it was found that the velocity co-efficients of reaction carried out under identical conditions, but on different days and even on different times of the same day, were slightly different. Titoff also made more or less

similar observations. From our experiments we find that cane sugar, lactose, glucose are very strong negative catalysts in the oxidation of Na_2SO_3 by air. It appears probable that the sugars as a class will act as marked negative catalysts. It has been found that sparingly soluble volatile organic substances like camphor, menthol, etc., have marked negative effect whilst naphthalene, anthracene have practically no effect. It is rather surprising that weak acids like acetic, propionic, cacodylic etc., have comparatively small retarding effects; their sodium salts also exert practically the same effect as the acids. On the other hand, comparatively stronger acids like oxalic, salicylic, benzoic etc., exert much greater retarding effect and their sodium salts too exert the same effect as the acids. Moreover it has been observed that sodium salts of strong inorganic acids have no marked effect. We have observed that hydraquinone has a very marked negative effect on this reaction for the same concentrated, it exerts the greatest negative effect among the catalysts investigated up till now. Consequently during the war hydroquinone was used as a preservative in Na_2SO_3 which was sent to places like Mesopotamia, Baghdad and other hot countries. Curiously enough the temperature co-efficient of the oxidation of Na_2SO_3 by oxygen unlike that of most other heterogeneous reactions is about two between the temperature interval of 25° to 35°. It has been observed that so long as 1/3 of the substance is oxidised the unimolecular velocity co-efficients remain practically constant, but as oxidation proceeds further the velocity co-efficient increases rapidly, as the reaction is autocatalytic.

Mathews and his collegues (Jour. Phys. Chem. *17*, (1913) 211; Jour. Amer. Chem. Soc. *39* (1917) 635) have found that ultraviolet light markedly accelerates the oxidation of Na_2SO_3 by oxygen or air. For this photochemical reactions they could not find a positive

catalyst. Copper sulphate which is known to be a powerful positive catalyst for the dark reaction exerted no effect in ultraviolet light. On the other hand, the negative catalysts like hydraquinone, phenol, etc exert a retarding effect in presence of ultraviolet light, so it appears that there exist a very few positive catalysts, but very many negative catalysts for this reaction, when carried out in light or in dark. The explanation of the negative catalystic effect of organic substances advanced in our paper is this—"The reaction consists in oxidation of SO_3 ions to SO_4 ions, the undissociated portion of Na_2SO_3 seems to be inactive. It is well known that several organic substances form complexes with H_2SO_3 and sulphites. Hence it is very likely that substances like hydraquinone, cane sugar, grape sugar etc., would form complexes with the sulphite *ion* and would thus decrease the concentration of sulphite *ion* which is supposed to be the active substance in this oxidation."

In the same paper the insufficiency of Luther's views (Zeit. Phys. Chem. *45*, (1903) 662) to explain negative catalysis was also pointed out. Luther advanced the idea that negative catalysis cannot take place in a reaction which is entirely free from positive catalysts, and the phenomenon is really due to the destruction or otherwise rendering latent of these positive catalysts. Titoff is of opinion that the oxidation of Na_2SO_3 proceeds with a measurable velocity in the presence of some catalytic agent, say $CuSO_4$. Mannitol acts as negative catalyst on this reaction. Titoff also studied the combined effect of negative and positive catalysts on the rate of oxidation of Na_2SO_3 and from his results he lent support to Luther's view, which seems to be very doubtful from the following reasons. According to Luther a negative catalyst must have a positive catalyst as its counterpart; but this is not probable since there are

so few positive catalysts and so many negative catalysts in most chemical reactions.

In previous papers (Dhar. Jour. Chem. Soc. *111*, (1917) 707; Annales de chimie, I have observed that manganous salts act as powerful negative catalysts in many oxidation reactions notably the oxidation of formic and phosphorous acids by chromic acid, oxidation of sodium formate by Iodine or $AgNO_3$ or $HgCl_2$ oxidation of ferrous salts by $AgNO_3$ etc. It is well known that manganous salts can readily pass into the manganic state.

I have observed that in the oxidation of oxalic acid by chromic acid, molybdic acid, boric acid, and excess of H_2SO_4 are negative catalysts. Similarly $NaNo_3$, NH_4NO_3, NaCl, NH_4Cl, LiCl, $MgCl_2$, $CdCl_2$, $Cr_2(So_4)_3$, $ZnSO_4$, $CuSO_4$, $NiSO_4$, K_2SO_4, Na_2SO_4, $K_2C_2O_4$, $MgSO_4$, $(NH_4)_2SO_4$, NaF etc. are negative catalysts whilst only manganous salts $K NO_3$, KCl are positive catalysts. In the oxidation of formic acid by chronic acid manganese salts, $K NO_3$, KCl, K_2SO_4, $Na NO_8$, Na Cl, $Na_2 SO_4$, NH_4NO_3, NH_4Cl, $(NH_4)_2 SO_4$, Li Cl, ammonium molybdate, $ZnSO_4$, $CoSO_4$, $Co(NO_3)_2$, $CoCl_2$, $Li NO_3$, NaF, $Ca(NO_3)_2$, $CaCl_2$, $SrCl_2$, $Sr(NO_3)_2$ $Ba(NO_3)_2$, $MgCl_2$, $MgSO_4$ are negative cataylsts, whilst H_2SO_4 $CdCl_2$, $Cd (No_3)_2$, $ZnCl_2$ and $Zn(NO_3)_2$ are positive catalysts. In the oxidation of sodium formate by iodine manganous salts, NaCl, NaBr, KBr, $Li(No_3)$ $Ba(NO_3)_2$, $Sr(NO_3)_2$, $Mg(SO_4)$, $Zn(NO_3)_2$, $Co(NO_3)_2$, $Co(SO_4)$, $NiSO_4$, $NiCl_2$, $Cr_2 (SO_4)_3$ etc., are negative catalysts. Whilst $K NO_3$, KCl, K_2SO_4, NH_4NO_3, $NaNO_3$, Na F, $Na_2 SO_4$ and Cd salts are accelerators. In the oxidation of H COO Na by mercuric chloride, manganous salts, $Li NO_3$, $MgSO_4$, $Ba(NO_3)_2$, $Sr (NO_3)_2$, $Ca (NO_3)_2$, $Zn(NO_3)_2$, $Co (NO_3)_2$, $CoSO_4$, $Ni SO_4$, $Cr_2 (SO_4)_3$ etc., are negative catalysts, whilst $K NO_3$, $K_2 SO_4$, $Na NO_3$

35

Na_2SO_4, CH_3COONa, and NaF are positive catalysts. In the oxidation of $HCOONa$ by $AgNO_3$ only KNO_3 is an accelerator whilst K_2SO_4, $NaNO_3$, Na_2SO_4, NaF, $LiNO_3$ NH_4NO_3, $Ba(NO_3)_2$, $Sr(NO_3)_2$, $Ca(NO_3)_2$, $MgSO_4$, $ZnSO_4$, $Cd(SO_4)$ $Cd(NO_3)_2$ etc., are negative catalysts. In the oxidation of $FeSO_4$ by iodine an excess of H_2SO_4 is a marked negative catalyst while no positive catalyst has been found for the above reactions. Consequently from our experiments we find that the number of negative catalysts are more numerous than the number of positive catalysts, thus our results do not support Luther's view about negative catalysts. Whilst investigating the mechanism of some induced reactions I was struck by the fact that the velocity of oxidation of Na_2SO_3 by air is markedly retarded by the presence of sodium arsenite. This observation led to a thorough investigation of the phenomenon of negative catalysts from several points of view and my results and conclusions were embodied in a paper (Dhar. Proct. K. Akad. Wetensch, Amsterdam *29* (1921) 1023) in which I stated that the phenomenon of negative catalysis is possible when the catalyst is likely to be oxidised. The following lines of arguments were advanced in that paper.

It is well known that a solution of sodium arsenite is not oxidised by atmospheric oxygen under ordinary conditions. On the other hand a solution of sodium sulphite is readily oxidised to sodium sulphate. Now if we mix the two together both the oxidations take place simultaneously. At the same time a curious phenomenon takes place. The velocity of the oxidation of sodium sulphite becomes very small in presence of sodium arsenite, that is sodium arsenite which is undergoing a slow oxidation acts as a powerful negative catalyst in the oxidation of sodium sulphite. Similarly a solution of an oxalate which also undergoes slow oxidation in presence of sodium

sulphite, which itself is being oxidised decreases to a marked extent the oxidation of sodium sulphite by atmospheric oxygen. It appears probable, therefore, that the phenomenon of negative catalysis is possible only when the catalyst is liable to be oxidised. These cases are of great importance in connection with the controversial question of negative catalysis.

In a previous paper (Jour. Chem. Soc. (1917) *111*, 707) I have shown that manganous salts act as powerful negative catalyst in the oxidation of formic and phosphorous acids by chromic acid and manganous salts can easily pass into the manganic state. Moreover it has been shown by myself as well as by other workers that various organic substances notably hydraquinone, brucine etc., act as negative catalysts in the oxidation of sodium sulphite by oxygen, and all these organic substances are themselves readily oxidised. It is well known that the oxidation of phosphorous by oxygen of the air is retarded by vapours of various organic substances *e. g.*, ether, turpentine, alcohol, etc., and the oxidation of chloroform is retarded by the presence of a small quantity of alcohol. Now all these negative catalysts are good reducing agents and are themselves readily oxidised. Hence in oxidation reactions, the phenomenon of negative catalysis takes place when the catalyst itself is liable to be readily oxidised.

A study of the slower oxidation that takes place at ordinary temperatures has not only shown that the process of oxidation is complicated by the presence of water but the question has been raised that just so much oxygen takes part in the induced reactions as combine with the substance undergoing oxidation.

Schönbein (Jour. Proct. Chem. *75* (1858) 99; (1894) *93*, 25; *105* 226, (1868) first noticed that when certain substances are undergoing oxidation spontaneously

in atmospheric oxygen, one part of oxygen combines directly with the substance, undergoing oxidations whilst another part of it is converted into ozone H_2O_2 or simultaneously oxidises some other substance. Schönbein (loc. cit) still further demonstrated that just so much oxygen is rendered active as is consumed by the substance which is being oxidised. Hence in all slow oxidations the same amount of oxygen is required as is consumed in the formation of H_2O_2 from water, or is utilised in the induced oxidation.

Later investigators like Jorissen (Zeit. Phys. Chem. (1897), *23* 667), Engler and Wild (Ber *33* 1901, 1000) have verified the law of Schönbein in several cases. If we expose a mixture of Na_2SO_3 and sodium arsenite to atmospheric oxygen according to Schönbein (loc. cit), one atom of oxygen should go to oxidise Na_2SO_3 while the other atom would oxidise a molecule of sodium arsenite in the same time. The oxidation of sodium arsenite is a very slow chemical change and in order that Schönbein's law be applicable it follows immediately that the oxidation of Na_2SO_3 which is fairly rapid becomes a slow change and the velocity of this oxidation becomes equal to that of the oxidation of sodium arsenite, because the same amount of oxygen will be taken up by the reducing agents in the same time. As a matter of fact from my experiments I have observed that in presence of sodium arsenite or potassium oxalate the velocity of oxidation of sodium sulphite becomes very small. We assume that a molecule of oxygen splits up in this reaction into two atoms and each atom oxidises one of the reducing agents. Now as a solution of Na_2SO_3 is much more readily oxidised than a solution of sodium arsenite it becomes difficult to understand why the other oxygen atom instead of attacking the readily oxidisable unacted Na_2SO_3 attacks the much more difficult oxidisable sodium arsenite, or if we assume that at first a peroxide of the type Bodlander's benzoyl peroxide

(Ahrens sam *3* 470 1899)) is formed as a combination o sodium sulphite with a molecule of oxygen. We are still encountered with the same difficulty. In this case we will have to assume that this peroxide instead of attacking the readily oxidisable and unattacked sodium sulphite will attack the less readily oxidisable sodium arsenite by preference. It seems to me therefore that the only course left to us is to find out the explanation on the view of the formation of a complex sulphite and arsenite or of sulphite and oxalate and that this complex is oxidised as a whole. It is well known that complex oxalates and sulphites do exist. Ostwald thinks that in order to explain positive catalysis by the hypothesis of intermediate compound formation it is necessary to show that the intermediate reactions actually take place more readily than the direct reactions under the given conditions, because if a reaction goes more slowly *via* the intermediate product than the direct part it will take the later and the possibility of the formation of intermediate products can have no influence on the process; "Hence" adds Ostwald "I see no possibility of explaining retarding catalytic influences by the intermediate products" (Nature 1902 *65* 522).

I have observed in a previous paper (Proc. Akad. Wet. Amsterdam *23*, (1920) 299) that the oxidation of sulphites and sulphurous acid, the sulphite *ion* is the active agent. If we can decrease the sulphite *ion* we can decrease the chemical change and a solution of sulphurous acid which is a weak acid containing few sulphite *ions* is oxidised less readily than a solution of sodium sulphite of the same concentration. On the addition of an arsenite to a sulphite a complex which itself is oxidised as a whole is formed. At the same time the velocity of oxidation of the sulphite becomes less due to the decrease in the concentration of the sulphite *ions* arising out of the formation of a complex of sulphite and arsenite or of

sulphite and oxalate. Here it seems to me that the only plausible explanation of this negative catalysis stands on the hypothesis of the formation of an intermediate complex compound.

Since the publication of the above results and conclusions, several workers have paid attention to the problem of negative catalysis. In a series of very interesting researches, Moureu and Dufraisse (Comt. rend. *174* (1922) 258; *175* (1922) 127; 176 (1923) 624, 797, *178* (1924) 824, 1397, 1862; *179* (1924), 237) have studied the absorption of oxygen by substances like benzaldehyde, acrolein, acetaldehyde, propaldehyde, chloral, cinnamicaldehyde, anisic aldehyde, hydrocinnamic aldehyde, furfurol, styrol, essence of turpentine, butter etc., in presence of phenol thymol, catechol, resorcinol, pyragallol, α naphthol, β napthol, gallic acid, salicylic aldehyde, tannin, ortho-nitrophenol orthoaminophenol, hydroquinone etc. They have found that all these substances act as negative catalysts in the oxidation of the first group of substances by air. They have observed that hydroquinone, pyrocatechol, pyrogallol are the best retarders. It is well known that these substances are very good reducing agents. Moureu and Dufraisse have thrown out the suggestion that the biological oxidation in animals and plants is possibly retarded and takes place at a desirable velocity because of the presence of phenolic substances in plants and animals. In plants phenols occur very frequently whilst in animals phenols hardly exist and that is probably the reason why life in plants and vegetables is slower and less intense than in animals, as phenols reduce the rate of oxidation by oxygen of substances in plants. Moureu and Dufraisse have also observed that in the absorption of the oxygen by acrolein, allyl iodide, iodo-benzone, ethylene, periodide two iodides of benzoylphenylacetylene are inactive, methyl iodide,

ethyl iodide, metheylene iodide, iodoform. carbon tetra iodide, acetylene di-iodide, chloride of iodobenzene, iodobenzne iodilobenzene, iodeosin etc., are accelerated in the oxidation of acrolein by oxygen. The following substances act as negative catalysts at first and then after some time they behave as positive catalysts. Methyl iodide Molar/80 (after few seconds), methylene iodide M/100 (15 minutes), Iodoform M/100 (20 hours), Carbon tetra-odide M/100 (after several days), ethylene iodide M/100 (8 hours), acelytene iodide M/1000 (18 hours) iodol M/1000 (90 hours), benzoyl iodide M/1000 (70 hours). M/1000 iodosobenzene acetate behaves at first as an accelerator and then as a retarder. In this connection it will be interesting to note that in a previous paper I have observed that H_2SO_4 at moderate concentration accelerates and in large excess retards the oxidation of oxalic acid by chromic acid (Dhar. Jour. Chem. Soc. *111* (1917) 707). Free iodine is at first a negative catalyst but after the decolourisation of the liquid acts as a positive catalyst. Moureu and Dufraisse have come to the conclusion that iodine either in ionic condition or in combination with organic substances acts as a negative catalyst. It is well known that iodides as well as organic iodine compounds can behave as reducing agents. Moureu and Dufraisse have suggested that the presence of iodine in plants and animals regulates the phenomenon of bio-chemical oxidation. It is very interesting to observe that in higher animals, which usually exist in a medium very poor in iodine content, the iodine is more or less concentrated in the thyroid gland which is supposed to be the regulator of oxidation in the animal body. Moureu and Dufraisse (Comp. Rend. *178*, (1924) 824) have shown that free iodine acts as a negative catalyst in the absorption of oxygen by benaldehyde, furfurol, and bromo styrol etc., whilst iodine has been found to be an accelerator in

the oxidation of styrol and some oils with oxygen. Iodides of potassium, litihium, silver, Ca, Mg, Zn, Hg, ammonium, dimethyl ammonium, trimethyl ammonium etc., act as negative catalyst in practically all these oxidation reactions. The Iodophenols also act as negative catalysts. Moureu and Dufraisse are of opinion that phenols and iodophenols act as negative catalysts and the mechanism of the negative catalysts are more or less indentical. Moureu and Dufraisse in their paper, (Comp. rend. *125*, (1924) 1862) have noted that the catalytic properties of substances as far as negative catalysis is concerned is connected with the tendency of these substances to be oxidised. As has been already emphasised we came to the same conclusion (Dhar. Proct. K. Akad. Wetensch *29*, (1921) 1023). Moureu and Dufraisse have observed that free sulphur and several of its compounds act as marked negative catalysts in several of the oxidation reactions. The following results were obtained by Moureu and his co-workers (Comp. Rend. *179*, 1924 237). In the absorption of oxygen by benzaldehyde the following substances were negative catalysts, P_4S_3, thio phenol, ethyl, xanthogen anilide, methyl xanchogen, amidediphenyldisulphide, potassium ethyl xanthrogenate, diphenyl thiourea, ethyl xanthogenamite, sodium methyl and ethyl xanthrogenates. Moreover sulphides of As, Sb, Bi, Sn, Na, Zn, Cd, Fe, Ni, Pb, Cu, etc., thiourea, thio sinnamine, thio lactic acid, thio hydracrylic acid, ethyl diaxnthogen, ethyl sulphide, methyl sulphide, diethylsulphide, dimethylsulphide, ethylmercaptan, monothio hydraquinone and its carboxy ethyl esters, thio diglycol, methyl xanthogenate of methyl, phenyl sulphide, ethyl disulphocyanide, sulphocyanate of K, NH_4 guanidine, Na_2SO_3, NH_4HSO_3 etc., act also as negative catalysts in the absorption of oxygen by benzaldehyde. It is a very curious fact that sulphides of Mn and Co act as positive catalysts in the oxidation of benzaldehyde by oxygen. With acrolein

the following results were obtained ethyl mercaptan, methyl and ethyl xanthogenamides, ethyl xanathogenamide, diphenyl thio urea, thio lactic acid, thio glycolic acid, thio phenol diethyl disulphide, dimethyl sulphide etc., are negative catalysts. Sulphur P_4 S_5, Sb_2 S_3, Mn S, Bi_2 S_3 alkaline xanthogenates, potassium ethyl carbonate, diphenyl disulphide etc., are without any action, ethyl sulphide, methyl sulphide etc., are positive catalysts. With turpentine, sulphur, antimony sulphide, Bi_2 S_3 are practically inactive, thiophenol, and manganese sulphide are accelerators whilst ethyl xanthogenamide, sodium and potassium ethyl xanthogenates, diethylene disulphide etc., are negative catalysts. P_4 S_3 is at first a positive catalyst and then it becomes a negative catalyst. With styrol, P_4 S_3, thiophenol, ethylmercaptan, antimony sulphide etc., are negative catalysts. Sulphur is inactive whilst ethyl xanthogenamide, potassium ethyl xanthogenate, diethylene disulphide, sodium ethyl xanthogenate, manganese sulphide etc., are negative catalysts. In the oxidation of sodium sulphide containing Na_2CO_3 the following results are obtained. Thio phenol, sodium methyl xanthogenate, sodium and potassium ethyl xanthogenates, sulphur, sodium sulphide, P_4 S_3 diethyl disulphide, sodium thio sulphate, ethyl xanthogenamide, manganese sulphide (green), Sb_2 S_3, thio urea etc., have been found to be negative catalysts, whilst sodium hyposulphide, copper sulphide, sodium and ammonium thio-cynate, manganese sulphide (rose) etc., are positive catalysts; when the sodium sulphite solution is neutralised using phenolphthalein as an indicator the following results are obtained in its oxidation by oxygen in presence of various catalysts. Sodium methyl xanthogenates, sodium sulphide, thio phenol, sodium thiosulphate, thio urea, potassium and sodium ethyl xantho genates etc., are negative catalysts. Whilst Bi_2 S_3, Sb_2 S_3, sodium hyposulphide, ammonium thio cyanate, green and red sulphide of manganese sulphur, potassium sulphocyanate, ethyl xanthogenamide, diethylene disulphide are positive catalysts.

It is practically impossible to explain from a single point of view satisfactorily all these diverse experimental results obtained by Moureu and his coworkers; but one thing is absolutely certain that majority of the substances investigated are negative catalysts in the absorption of oxygen by substances like benzaldehyde, turpentine, acrolein etc., and these negative catalysts are known to be good reducing agents. Recently Lifschlitz and Kalberar (Zeit. Phys. Chem. *102*, 1922 393) have shown that ether retards the slow oxidation of magnesium alkyl halides of the Grignard type, and this oxidation is revealed by luminescence on expossure of substances to air. Delepine (Compt. rend. *174* (1922) 1291) has shown that in the oxidation of several organic sulphur compounds, luminescence is observed and these substances themselves and other sulphur compounds can act as negative catalysts in their oxidation by air. In this connection it will be interesting to note the following observation of negative catalysis caused by sulphur compounds. As early as 1797 Berthollet observed that the luminescence of phophorus is hindered by traces of sulphurous vapours. Davy in 1817 observed that traces of H_2S retard the inflamation of a mixture of hydrogen and oxygen. Young (loc. cit) has observed that sulphur and hydrogen sulphide are positive catalysts in the oxidation of stannous salts by air. On the other hand, others have found that thio-urea and its salts, sodium hyposulphite, bisulphite of aldehyde act as negative catalysts in the oxidation of stannous salts by air.

It has also been shown that oxidation of India rubber is retarded during vulcanisation when a little sodium hyposulphite or Na_2SO_3 is added to the rubber. Moreover acetyl thio urea prevents fatty substances from being rancid and H_2SO_3 makes the solution of adrenaline stable. We have observed in a previous paper (Mittra & Dhar Zeit. Anorg. Chem. *122*, (1922) 146) that sodium thio sulphate

retards the oxidation of Na_2SO_3. It has also been observed that traces of sulphur retard the oxidation of paraffin by oxygen at a temperature of 135°C. It is evident from the foregoing results that all these negative catalysts in oxidation reactions are typical reducing agents.

It is believed that nitrous acid decomposes according to the following equation:—

$$3\ HNO_2 \rightleftarrows HNO_3 + 2NO + H_2O.$$

We are determining the velocity of this reaction in presence of different catalysts. We observe that the velocity of this reaction is greatly retarded in presence of glucose maltose, cane sugar, glycerol, etc. The decomposition of nitrous acid is really caused by the oxidation of some molecules of nitrous acid, to nitric acid and the reduction of certain other molecules to nitric oxide. Hence this is a case of auto-oxidation and reduction taking place simultaneously.

Consequently reducing agents like cane sugar, glucose, maltose, glycerol, etc., act as negative catalysts in this reaction involving auto-oxidation and reduction.

It is well known that phosphorous acid decomposes according to the following equation:

$$4\ H_3PO_3 = 3\ H_3PO_4 + PH_3.$$

Similarly hypophosphorous acid decomposes according to the equation:

$$2\ H_3PO_2 = H_3PO_4 + PH_3.$$

It appears probably that in these reactions involving auto-oxidation and reduction, reducing agents like sugars, glycerole etc., would be negative catalysts.

Consequently the experimental work available on negative catalysis has amply verified the accuracy of our statement that negative catalyst is readily oxidised. It has already been remarked that in our previous publication (loc. cit)

I have observed that the explanation of negative catalysis in the oxidation of $Na_2 SO_3$ in presence of sodium oxalate rests on the formation of a complex of sulphite and arsenite or of sulphite and oxalate, and this complex is oxidised as a whole. I am still of the opinion that this view satisfactorily explains at least qualitatively most of the phenomenon of negative catalysis hitherto investigated. In all these reactions oxygen is being slowly absorbed by the reducing agents *e. g.* benzaldehyde, sodium sulphite, acrolein etc. Now as these reactions are rather slow, it is certain that a very small amount of the reducing agents can combine with oxygen in a definite time and it seems certain that the negative catalyst, even when added in small quantities, is in sufficient quantity to combine and form a complex substance with the greater amount of the reducing agents in the reactive state; and that is why only traces of substances like hydraquinone, $P_4 S_3$, sulphur, mannitol, lactose etc., are sufficient to markedly retard the oxidation of benzaldehyde, $Na_2 SO_3$ etc., by air. In foregoing papers I have observed that traces of manganous sulphate markedly retard the oxidation of formic acid, phosphorous acid etc., by chromic acid. The oxidation of these acids by chromic acid are slow chemical changes. Consequently it seems certain that only a few molecules of formic acid or phosphorous acid are combining with chromic acid in a certain time. Hence very few molecules of manganous sulphate would be enough to combine with the reacting molecules of phosphorous acid or formic acid and would affect the velocity of reaction. Similarly we have observed that traces of glucose, lactose, cane sugar etc., are sufficient to retard appreciably the velocity of oxidation of $Na_2 SO_3$ by oxygen, consequently it seems very likely that the molecules of these negative catalysts combine with the reactive or active molecules of the reducing agents *e. g.* $Na_2 SO_3$, benzaldehyde, acrolein etc., and form molecular complexes.

In a recent paper (Dhar. Jour. Phys. Chem. 28, (1924) 948) I have advanced an explanation of induced reactions based on the generation of *ions* in slow reactions. It is well known that *ions* are generated in the oxidation of phosphorous. It is very likely that these *ions* can activate molecules of oxygen, which thus become reactive, and induce chemical changes which are not possible with molecular oxygen. Let us also consider the case of sodium sulphite and sodium arsenite when exposed to air. If the spontaneous oxidation of Na_2SO_3 by air or oxygen can generate *ions* these *ions* will activate the molecules of oxygen which then react with molecules of sodium arsenite. As the activated molecules of oxygen contain an excess of energy, they would readily combine with substances like sodium arsenite, oxalic acid etc., with which molecular oxygen cannot combine at the ordinary temperature. We know that Na_2SO_3 readily combines with molecular oxygen but activated molecules of oxygen would hardly differentiate between a molecule of Na_2SO_3 and of sodium arsenite because of their increased energy. Consequently an activated molecule of oxygen would be practically as good an oxidising agent towards Na_2SO_3 as towards sodium arsenite.

In the paper already referred to (Dhar. Proc, K. Akad. Wetensch. Amsterdam *29*, (1921), 1023) I remarked.

"Now as a solution of Na_2SO_3 is much more readily oxidised than a solution of sodium arsenite it becomes difficult to understand why the other oxygen atom instead of attacking the readily oxidisable unattacked Na_2SO_3 prefers to react with the more difficulty oxidisable sodium arsenite. Or if we assume that a peroxide of the type of Bodlander's benzoyl peroxide is formed as a combination of NaS_2O_3 with a molecule of oxygen, we are still encountered with the same difficulty. In this case we shall have to assume that this peroxide, instead of attacking the readily oxidisable Na_2SO_2 will react with the less readily oxidisable sodium

arsenite by preference". These difficulties can be easily met from the point of view of the activation of oxygen molecules due to the generation of *ions* in the spontaneous oxidation of sodium sulphite by oxygen. It has been already emphasised that the *ions* generated in the spontaneous oxidation of substances like phosphorous, sodium sulphite etc., can activate molecules of oxygen which thus become reactive and induce chemical changes which are not possible with molecular oxygen. Consequently with activated oxygen because of its extra amount of energy, sodium arsenite is practically just as good a reducing agent as sodium sulphite. Consequently in presence of sodium sulphite, sodium arsenite can be oxidised by atmospheric oxygen and the greater the quantity of Na_2SO_3 the greater will be the amount of oxidation of sodium arsenite.

Moureu and Dufraisse explain the anticatalytic action of substances like hydroquinone, pyrogallol etc., on the absorption of oxygen by benzeldehyde, acrolein, sodium sulphite etc., on the hypothesis of mutual destructions of peroxides. It is well known that hydrogen peroxide is decomposed by O_3, MnO_2, PbO_3, $KMnO_4$, HIO_2, periodic acid etc. Moureu and Dufraisse assume that a molecule of oxygen at first combines with a molecule of benzaldehyde and forms a peroxide. At the same time it has been assumed that a molecule of oxygen can combine with a molecule of the negative catalyst and would form a peroxide. Now these peroxides would destroy each other with the formation of the original substances and oxygen.

A (benzaldehyde)$+O_2 \longrightarrow AO_2$, B (negative catalyst) $+O_2 \longrightarrow Bo_2$

$$AO_2+BO_2 = A+B+2O_2$$

OR $\quad A+O_2=AO_2,\ AO_2+B=AO+BO=A+B+O_2$

They have observed that in positive catalysis the following reaction takes place:—

$BO+A=AO+B$, where AO is a stable oxide. Hence BO can be formed directly at the expense of B and oxygen or by the action of AO_2 on B. Now if the compound BO act more readily on A we have a case of positive catalysis but if BO acts more readily on AO we have a case of negative catalysis.

Moureu and Dufraisse have observed that free sulphur is a negative catalyst in the oxidation of benzaldehyde by oxygen. We know that benzaldehyde can form a peroxide with oxygen. In order to explain this negative catalysis according to Moureu and Dufraisse we have to assume that either a molecule of oxygen also react with sulphur forming a peroxide and this peroxide would react with the peroxide of benzaldehyde with the regeneration of benzaldehyde, sulphur and oxygen, or we have to assume that the peroxide of benzaldehyde will react on sulphur with the formation of benzoic acid and an oxide of sulphur and oxygen. From our chemical experience we know that these changes are rather unlikely. From a careful consideration of this case and other cases of negative catalysis I am of the opinion that the hypothesis of Moureu and Dufraisse as an explanation of negative catalysis based on the mutual destruction of two peroxides seems importable and far-fetched.

We have observed that sulphur can be oxidised to H_2SO_4 by air in presence of yellow phosphorus, cuprous oxide etc., which are undergoing oxidation.

Recently Jorissen and co-workers (Rec. Trav. Chimique *42*. (1923) 855; *43*, (1924), 582) have discussed some cases of induced reactions and activation of oxygen; they have observed that in presence of sodium sulphite, sodium antimonite can be oxidised by atmospheric oxygen. Jorissen has also discussed the researches of Moureu and Dufraisse in their relation to induced oxidations.

As far as I know I was the first to observe the phenomenon of negative catalysis in induced reactions and I was the first to make the following observations (Dhar. Proc. K. Akad Wetensch Amsterdam, *29*, (1921) 1023) "Now if we mix sodium arsenite and sodium sulphite together, both the oxidation take place simultaneously. At the same time a curious phenomenon takes place. The velocity of the oxidation of $Na_2 So_3$ becomes very small in presence of sodium arsenite, that is sodium arsenite which is undergoing a slow oxidation acts as a powerful negative catalyst in the oxidation of sodium sulphite. Similarly a solution of an oxalate which also undergoes slow oxidation in presence of $Na_2 So_3$, which itself is being oxidised decreases to a marked extent the oxidations of Na_2So_3 by atmospheric oxygen." In the same paper I remarked: "Later investigators like Jorissen (Zeit. Phys. Chem. *23* (1897) 667) Engler and Wild (Ber 33 (1900) 1090, 1097, 1109) and others have verified the law of Schonbein in several cases. If we expose a mixture of Na_2So_3 and sodium arsenite to atmospheric oxygen according to Schonbein (Loc cit) one atom of oxygen should go to oxidise Na_2So_3 while the other atom would oxidise a molecule of sodium arsenite, in the same time. The oxidation of sodium arsenite is a very slow chemical change and in order that Schonbein's law be applicable it follows immediately that the oxidation of Na_2SO_3 which is fairly rapid becomes a slow change and the velocity of this oxidation becomes equal to that of oxidation of sodium arsenite, because the same amount of oxygen will be taken up by the reducing agents in the same time". From the foregoing quotations it is clear therefore that the phenomenon of negative catalysis in induced reactions was first reported by me. What Jorissen, Engler, and Wild, and others did was to find out whether Schonbein's law is applicable to these oxidations or not. Jorissen

(Loc cit) has drawn attention to the formation of a peroxide of benzoyl acetyl in the oxidation of benzaldehyde and acetic anhydride in air or oxygen according to the following equation:—

$$2C_6H_5COH + (CH_3CO)_2O + 2O_2 \longrightarrow H_2O + 2(C_6H_5CO)(CH_3CO)O_2$$

In this induced oxidation of acetic anhydride there is distinct evidence of the formation of a molecular complex of a acetic anhydride and benzaldehyde and this complex is oxidised as a whole. We have already postulated the formation of a complex of arsenite and sulphite and we have assumed that this complex of arsenite and sulphite is oxidised as a whole when oxygen reacts with a mixture of sodium sulphite and sodium arsenite. We have already mentioned that we have been able to oxidise free sulphur into H_2SO_4 when it is mixed with yellow phosphorus, cuprous oxide etc. and that Moureu and Dufraisse have reported that sulphur is a good anticatalyst. It seems very likely therefore that in many of these reactions the negative catalyst like sulphur, hydro-quinone etc, are actually oxidised in presence of the reducing agents like benzaldehyde Na_2SO_3 etc., which are also undergoing oxidation. We have already observed that the oxidation of substances like sulphur, sodium arsenite, hydro-quinone etc., is possible with molecular oxygen under ordinary conditions but with activated molecules of oxygen rendered reactive by the absorption of *ions* generated in the spontaneous oxidation of substances like sodium sulphite benzaldehyde etc. Moreover in many cases the negative catalyst form additive compounds with one of the reacting substances, especially with reducing agents *e.g.* sodium sulphite, benzaldehyde, acrolein, turpentine etc., and this molecular complex is oxidised as a whole, consequently I am of opinion that in many cases the phenomenon of negative catalysis, induced oxidation and

the formation of molecular complexes would be essentially connected.

Recently Taylor (Jour. Phys. Chem. *27*. (1923) 322) has discussed the question of negative catalysis and has come to the conclusion that molecular complexes are formed in the decomposition of oxalic acid by $H_2 SO_4$ in presence of traces of water. He has also postulated the formation of molecular complexes in other cases of negative catalysis. On the other hand Christiansen (Jour. Phys. Chem. *28* (1924) 145) does not support the formation of molecular compounds. He has tried to explain negative catalysis on the hypothesis of breaking of a chain of the reacting substances. (Compare Bodenstein Zeit elektrochem *22*, (1916) 63) and Nernst Grund lagen des Neuen Warmesatzes 1918 134) I am of opinion that this conception of Christiansen is inadequate and there is no experimental support in its favour.

Summary.

1. In the oxidations of phosphorus, chloroform, sulphites, stannous salts, benzaldehyde, acrolein, and several other reducing agents by oxygen or air, readily oxidizable substances like hydroquinone, sugars, glycerol, sodium arsenite, several organic substances etc., act as negative catalysts. Similarly in many oxidation reactions, reducing agents behave as retarders. These results were coordinated by the present author in a paper published in 1921, in which it was observed that the phenomenon of negative catalysis in oxidation reactions, is possible when the catalyst is liable to be readily oxidized.

In this paper this conclusion has been amplified.

2. The decomposition of nitrous acid ($2\,HNO_2$ ——— $HNO_3 + 2\,NO + H_2O$ ———) is retarded by reducing agents like cane sugar, glucose, glycerol etc. Similarly it seems very probable that the decompositions of phosphorus and hypophosphorus acids would be retarded by readily oxidizable substances.

3. Many cases of negative catalysis were explained in the paper already referred to from this point of view of the

formation of molecular complexes of the catalyst, and the substance which is undergoing oxidation. This view it supported by the researches of other workers.

It is very likely that the phenomena of negative catalysis, induced reaction and the formation of molecular complexes are essentially connected.

STUDIES IN ADSORPTION

Influence of ions carrying the same charge on (a) coagulation of diluted sols (b) coagulation by mixed electrolytes and (c) acclimatization.

S. GHOSH and N. R. DHAR.

In foregoing papers of this series [Jour. Phys. Chem. *26*, 701 (1922); *28*, 313 (1924); Koll Zeit (1924)] we have studied the influence of the change of concentration of a sol on its coagulation by electrolytes. We enunciated the general dilution rule that the greater the concentration of a sol, the greater is the amount of electrolyte necessary for coagulation irrespective of the valency of the precipitating ion. Sulphides of arsenic and antimony are exceptions to the above rule when precipitated with univalent electrolytes. It has been observed that the coagulation of these sulphide sols by bivalent and trivalent cations practically follow the general rule that the greater the concentration of the sol the greater is the amount of electrolyte necessary for coagulation. This general dilution rule has been found applicable to manganese dioxide sol, positively and negatively charged ferric hydroxide, positive and negative chromium hydroxide, prussian blue, $Al(OH)_3$ suspended in organic acids etc. In this paper it will be found that this rule is valid with negative stannic hydroxide. In our attempt to explain the abnormal behaviour of As_2S_3, Sb_2S_3—sols on dilution in their coagulation by univalent salts, we have established the following facts:—

(1) We have proved that it is impossible to prepare a pure arsenious sulphide sol. Arsenious sulphide is readily hydrolysed according to the following equation

$AS_2S_3+3H_2O \rightleftarrows AS_2O_3+3H_2S$. As soon as the sol of arsenious sulphide is freed from H_2S by passing hydrogen, some arsenious acid is immediately set free; hence it is not practicable to prepare a pure sol of arsenious sulphide. It has been repeatedly observed that when all free H_2S is removed from a sol of AS_2S_3 appreciable amount of arsenious acid is always present along with the arsenious sulphide, the free arsenious acid can be detected by coagulating the colloid and testing for arsenious acid in the clear filtrate. The amount of arsenious acid increases with the time during which hydrogen is passed. The amount of arsenious acid also goes on increasing if the sol is kept at the ordinary temperature. If hydrogen is bubbled for about three or four hours in freshly coagulated, well washed arsenious sulphide suspended in water, appreciable amount of arsenious acid appears in the filtrate. Hence the sols of arsenious sulphide always contain free arsenious acid.

(2) We have also proved that free arsenious acid has a coagulating effect, whilst free H_2S has a stabilising effect on arsenious sulphide sol in its coagulation by univalent cations. We have also proved that in equivalent concentrations, H_2S exerts more influence as a peptising agent than arsenious acid as a coagulating agent, towards arsenious sulphide sol when it is coagulated by potassium chloride. When arsenious sulphide sol is diluted, more and more of free H_2S and arsenious acid are formed. As will be seen in the equation, the amount of H_2S set free by hydrolysis of AS_2S_3 is greater than the amount of arsenious acid liberated, when the concentrations of both H_2S and arsenious acid are expressed iodometrically. The H_2S set free tries to peptise the unhydrolysed arsenious sulphide whilst the arsenious acid tries to coagulate the sol. The net effect of these opposing influences is that the sol is really stabilised on dilution

because the influence of H_2S which is a product of the hydrolysis more than counterbalances the coagulating influence of arsenious acid. Hence dilution according to these results should stabilise arsenious sulphide sol towards potassium chloride and the experimental results are in support of this conclusion. On the other hand, from our experimental results we find that arsenious sulphide sol is not stabilised but becomes unstable by the presence of H_2S when coagualted by bivalent and trivalent electrolytes. Consequently when the sol is diluted and is hydrolysed more and more, it becomes more unstable than the concentrated sol towards bivalent and trivalent cations. Hence the dilute sol would require less bivalent and trivalent electrolytes for coagulation than the concentrated one and experimental results are in favour of this conclusion.

(3) We have proved that negatively charged hydrated manganese dioxide not only adsorbs cations but it also adsorbs appreciable quantities of anions and hydroxide ions. We have also proved that barium suphate in the course of its formation leaves the basic part free, but it also adsorbs the positive ions as the following experimental results will show :—

Table I.

Electrolyte.	Original conc. of cation.	Final conc. of cation.	% adsorption.
KCl	0·1038 M	0·1032 M	0·1 %
$K_2C_2O_4$	0·06894 M	0·06753 M	2·0 %
KB_2O_3	0·09400 M	0·09336 M	0·6 %
Na_3AsO_3	0·08833 M	0·08532 M	3·7 %

In a foregoing paper (Sen and Dhar Koll. Zeit. *34*, 262 1924) it has been observed that C SO''_4, $C_2O''_4$ ions etc., are adsorbed by arsenious sulphide when it is

coagulated by KCl, K_2SO_4, $K_2C_2O_4$ etc. In another paper (Ghosh and Dhar Koll. Ziet. 1924) the following quantitative experiment has been made with KCl and AS_2S_3 sol.

Adsorption of potassium and chiorine ions

Amount of As_2S_3 = 0·4508 grm. and volume = 100 cc.

Original concentration.	Final concentration.	Adsorption.
0·05997 Cl′	0·05900 Cl′	1·6 %
0·05997 K·	0·05790 K·	3·3 %

Hence the ratio of adsorption of potassium ion to that of chloride ion is 2·06.

(4) In a foregoing paper [Dhar, Sen and Ghosh Jour. Phys. Chem. *28*, 457, (1924)] it has been proved that the real interpretation of the Schulze-Hardy Law is that the greater the valency of an ion, the less is the adsorption, and this is also corroborated by the experimental results obtained by us as well as by other workers.

The exceptional cases have been explained on the view that the neutralised particles can absorb the precipitating electrolyte.

There is another plausible view which also can explain the exceptional cases. Let us consider the coagulation of positively charged $Fe(OH)_3$ by $K_2C_2O_4$ and $K_2Cr_2O_7$ [Compare Weiser, Jour. Phys. Chem. *25*, 399 (1921).]. It is observed that the precipitation value and the amount of adsorption of the oxalate ion are much greater than those of the dichromate ion. It is likely that the sol will adsorb more of the positive ion in one case than in the other.

Experiments on the precipitation of barium sulphate already noted in presence of potassium chloride and of oxalate show that the adsorption of exalate ion is much greater than that of chloride ion (12% with oxalate and 2% with chloride at the same molecular concentration)

though according to the Schulze-Hardy Law it should be otherwise. We have found out that along with the adsorption of oxalate ion by barium sulphate, appreciable quantities of potassium ion is also adsorbed. The positively charged substance, barium sulphate can adsorb potassium ions and hence more of the oxalate ion would be necessary for its charge neutralisation and precipitation.

(5) When KCl is added to As_2S_3 sol, it will attract and adsorb the positive ion. It may also adsorb the negative ion and molecular KCl. Now when the charge on the sol is neutralised by the adsorption of positive ions, the neutralised particles can easily adsorb Cl' ions because of the chemical attraction of the sol for Cl' ions. It is quite probable that when the charge on the sol becomes sufficiently small due to the adsorption of potassium ions, they might attract the chloride ions because of the chemical attraction which counterbalances the repulsive force due to the sameness of the electric charge.

The adsorption of negative ions like Cl', SO_4'', C_2O_4'' etc. will certainly stabilise the sols of As_2S_3, Sb_2S_3 etc. and the stability of a sol in respect to its coagulation by a certain electrolyte will depend on the ratio of the amounts of adsorption of the two ions of the electrolyte. For example, when KCl is added to As_2S_3 sol, it will adsorb both the ions, as has been shown experimentally, but the potassium ion is adsorbed more than the chloride ion and hence the sol is actually coagulated by the electrolyte.

In the case of bivalent salts like $BaCl_2$, $SrCl_2$, etc. and trivalents salts like $AlCl_3$, $FeCl_3$ etc. the ratio of the amounts of adsorption of the positive to the negative ion is undoubtedly much greater than unity in all concentrations of the sol. This is the reason why the rule that

the greater the concentration of the sol, the greater is the concentration of the electrolyte necessary for the coagulation is applicable in all these cases.

In the case of univalent salts like KCl, LiCl etc., with negatively charged sols As_2S_3, Sb_2S_3 etc., the ratio of the amounts of adsorption of positive ions to the negative ions is usually greater than unity. It seems probable that when the concentration of these sols becomes small this ratio tends to decrease and may approach unity. That is why more and more KCl or LiCl is necessary to coagulate a dilute sol of As_2S_3 or Sb_2S_3, than concentrated sols of the same substance.

We are trying to show experimentally that the ratio of the amounts of adsorption of positive ions to the negative ions decreases with dilution of the sols in their coagulation with KCl.

In cases of positively charged ferric hydroxide, chromium hydroxide etc. the adsorption of the positive ion is very small in comparison with that of the negative ion. The ratio of the amounts of adsorption of the negative ion to that of the positive ion is always greater than unity and does not much change with the concentration of the sol. For this reason, the general rule that the greater the concentration of the sol, the greater is the amount of electrolyte necessary for coagulation is applicable in all dilutions of these sols with all electrolytes.

(6) From a critical summary of the existing data on the coagulation of sols by electrolytes we have observed that the effect of positive ions on positively charged sols like $Fe(OH)_3$, $Cr(OH)_3$ etc. is not so marked as that of negative ions in the case of negatively charged sols like As_2S_3, Sb_2S_3 etc. Thus from Linder and Picton's results with chlorine as the precipitating ion, the average precipitation value of different univalent salts becomes 283 in the case of ferric hydroxide sol, and the average

precipitation value with bivalent salts is about 305, the difference is 7%. On the other hand the precipitation value of univalent salts on arsenious sulphide sol is 99·4 and that of the salts containing bivalent negative ions is 130 showing a difference of 30%. These results can be satisfactorily explained on the assumption that negatively charged arsenious sulphide can adsorb appreciable quantities of the ion carrying the same charge, whilst positively charged ferric hydroxide can hardly adsorb an ion carrying a positive charge.

In this connection it should be noted that the influence of the ion carrying the same charge as the sol on its coagulation has been emphasised by Bancroft (Second Report on Colloid Chemistry Brit. Assoc. 1919, p. 2; Burton and Bishop (Jour. Phys. Chem. *24*, 701, 1920), Ostwald (Koll. Zeit. *26*, 28, 69 (1920), Weiser (Jour. Phys. Chem. *25*, 665, 1921; 742; *28*, 232, 1924) and others. Weiser has given this idea a great prominence in explaining many facts in the coagulation of sols by electrolyte. But as far as we know we were the first to observe experimentally (qualitatively and quantitatively) that ions carrying the same charge are actually adsorbed by sols and we have co-ordinated diverse facts on coagulation and adsorption from this point of view.

In the foregoing paper of this series (Ghosh and Dhar. Kolloid Zeit. 1924) we have reported that the presence of free sulphur in colloidal arsenious sulphide can be detected by treating the coagulating mass of arsenious sulphide by carbon disulphide. It seems likely that the presence of this negatively charged sulphur sol adds to the stability of arsenious sulphide sol, which is also negatively charged. Consequently a boiled sol of arsenious sulphide is more stable towards all electrolytes.

Recently Murphy and Mathews [Jour. Amer. Chem. Soc. *45*, 16, (1923)] have proved that arsenious sulphide

sol does not contain a simple compound such, for example, as the molecule As_2S_3.

It is very likely most sulphide sols would be contaminated with negatively charged sulphur sol. Hence antimony sulphide or mercuric sulphide sol does not contain simple compounds, such as, Sb_2S_3, HgS, but really is a mixture of two or more sols or of different molecular species.

In the case of mastic, which is a naturally occurring resinous matter, we are probably dealing with a mixture of different substances.

It is interesting to note that these very substances *e.g.* arsenious sulphide, antimony sulphide, mastic etc. show abnormal dilution effect towards univalent cations.

The sulphide sols are partially decomposed on boiling or on keeping for a long time at the ordinary temperature. Moreover, these sols undergo hydrolysis readily and are also oxidised easily.

It appears, therefore, that sols, which are liable to be hydrolysed or to undergo other chemical changes readily are likely to show complications in their coagulation with electrolytes.

In part VII of this series [Sen and Dhar Koll. Zeit. *34*, 262 (1924)] the following observations were made:—

"The adsorption of negative ions like Cl′, SO_4'', C_2O_4'' etc. by negatively charged sols explain some interesting observations of Linder and Picton [Jour. Chem. Soc. 1895, *67*, 67, (1895)] and of Weiser [Jour. Phys. Chem. *25*, 665, (1921)].

They have found out that at the beginning if small quantities of KCl, NaCl, LiCl etc. are added, the sol of arsenious sulphide, becomes more stable towards electrolytes $BaCl_2$, $SrCl_2$ etc. Whilst ferric hydroxide sol is not stablised towards K_2SO_4, $K_2C_2O_4$ etc. by the previous addition of KCl, $KBrO_3$, KNO_3 etc.

Very little work has been done on the precipitation of colloids by mixtures of electrolytes. Linder and Picton (loc. cit), Freundlich and co-workers [Zeit. Phys. Chem. *44*, 145, (1903), Kolloid Chem. Beihefte *16*, 267 (1922)], Blake [Amer. Chem. Jour. *16*, 438 (1903)], and Weiser (loc. cit) have investigated the coagulation of some sols by a mixture of electrolytes.

The important facts observed are: (1) with positive ferric hydroxide, positive chromic hydroxide and negative stannic hydroxide, the precipitating values of mixtures of pairs of electrolytes of widely varying precipitating power (uni- and bivalent ions) are slightly less than the additive values. Thus mixtures of KCl and either K_2SO_4 or $K_2C_2O_4$ precipitate ferric hydroxide and chromic hydroxide at concentrations less than the additive values, and the same is true for mixtures of LiCl and either $BaCl_2$ or $MgCl_2$ with negative stannic hydroxide. The maximum difference between the observed and the calculated values is less than 20%.

(2) With the above sols an approximately additive relationship is obtained with a mixture of bivalent precipitating ions.

(3) With As_2S_3 the same is true for mixtures of (*a*) NH_4Cl and HCl, (*b*) $Ca(NO_3)_2$ and $BaCl_2$ and (*c*) $BaCl_2$ and $MgCl_2$.

(4) With As_2S_3, the precipitating values of mixtures of electrolytes of widely varying precipitating powers are always much greater than the additive values. This was observed with (*a*) LiCl and $MgCl_2$ (*b*) LiCl and $BaCl_2$, (*c*) HCl and $MgCl_2$, (*d*) KCl and $SrCl_2$, (*e*) KCl and $BaCl_2$.

The difference between the observed and the calculated values is as high as 120% in certain cases.

In explaining the behaviour of a mixture of electrolytes in the precipitation of colloids Weiser has emphasised two factors:

1. The effect of the presence of each precipitating ion on the adsorption of the others.

2. The stabilising action of the ions having the same charge as the colloid.

If the influence of both these factors be small the precipitation value of mixtures would be additive, whilst if the influence of both these factors be large the precipitation value of mixtures will be greater than that expected from the values for the two different salts. Recently Weiser (loc. cit) has shown that the relatively large amount of chloride ion has no appreciable effect on the adsorption of oxalate ions by chromium hydroxide. The same is true, as Weiser has shown, in the case of ferric hydroxide and that is why no ionic antagonism is observed in the precipitation of chromium hydroxide or ferric hydroxide by a mixture of potassium chloride and oxalate. On the other hand, Weiser has shown that the adsorption of barium ion is decreased to a marked extent by the presence of lithium ion in the coagulation of arsenious sulphide. Freundlich and Scholz (loc. cit) are of the opinion that the extent of hydration of a colloid is the most important factor in causing the ionic antagonism which results in precipitation values for certain mixtures of electrolytes that are considerably above the additive values. It is very difficult to understand how the hydration of the sol or that of the precipitating ion can explain ionic antagonism.

Moreover it is so difficult to ascertain the amount of hydration of a sol or an ion [compare Dhar, Zeit. Elektro Chem. *20*, 57 (1914)].

EXPERIMENTAL RESULTS.

Stannic Hydroxide Sol.

In this paper we have studied the coagulation of negatively charged stannic hydroxide sol by different

electrolytes and at various dilutions. The sol was prepared by slowly adding stannic chloride solution to a dilute caustic soda solution till the mixture was practically neutral. The sol was dialysed for about 3 days, when it was free from any alkali. The sol was practically optically clear and very stable. It will be seen from the following table that this sol follows the Schulze-Hardy Law in general and the rule that the greater the concentration of the sol the greater the amount of electrolyte necessary for the coagulation, irrespective of the valency of the precipitating ion.

Concentration of the sol=2·71 grs SnO_2 per litre.

Volume of sol taken each time=4c.c.

Volume after mixing electrolyte=6c.c.

Time=$\frac{1}{2}$ hr.

Electrolyte.	Conc.	Amount added. c.c.	Ppt. Concentration.
KCl	$\frac{N}{2}$	1·30	0·1083
K_2SO_4	$\frac{N}{2}$	1·40	0·1167
K_4FeCN_6	$\frac{N}{2}$	> 2·0	———
$BaCl_2$	$\frac{N}{125}$	0·9	0·0012
$MgCl_2$	$\frac{N}{100}$	1·2	0·0020
$Al_2(SO_4)_3$	$\frac{N}{250}$	1·45	0·0009
$Th(NO_3)_4$	$\frac{N}{200}$	1·25	0·0012

An examination of the above table gives the following order for the precipitation values, beginning with the highest one—$K_4 Fe CN_6 > K_2SO_4 > KCl > MgCl_2 > BaCl_2$, $Th (NO_3)_4 > Al_2 (SO_4)_3$.

From the experimental results, it appears that the Schulze-Hardy Law is applicable in this sol with the

exception of thorium, which has been found to behave abnormally in other cases, such as As_2S_3, Sb_2S_3, negatively charged $Cr(OH)_3$ [Sen and Dhar, *34*, 262, (1924)] etc.

Since the colloid is negatively charged it is obvious that the cation is the coagulating agent. It appears, however, the anions also have appreciable influence as shown in the following table:—

Electrolyte	Conc.	Amount added c.c.
KCl	$N/_2$	1·3 c.c.
K_2SO_4	$N/_2$	1·4
$K_4Fe\ CN_6$	$N/_2$	>2·0

The precipitation values of different salts with the same cation are in the order $K_4Fe\ CN_6$ > K_2SO_4 > KCl.

It is interesting to observe that salts like potassium citrate, potassium ferrocyanide, etc., precipitate negatively charged stannic hydroxide with great difficulty. Exactly similar results were obtained with negatively charged ferric hydroxide and chromium hydroxide due to the great peptising influence of polyvalent negative ions.

Effect of dilution.

Electrolyte	Sol A c.c.	Sol $\frac{A}{2}$ c.c.	Sol $\frac{A}{4}$ c.c.
KCl $\frac{N}{2}$	1·3	1·2	1·1
$BaCl_2$ $\frac{N}{125}$	0·9	0·6	0·35
$MgCl_2$ $\frac{N}{100}$	1·2	0·7	0·4
$Al_2(SO_4)_3$ $\frac{N}{250}$	1·45	0·8	0·4

KCl $\frac{N}{2}$	$BaCl_2$ $\frac{N}{125}$ added	$BaCl_2$ $\frac{N}{125}$ Cal.	Difference.
0·6 c.c.	0·45 c.c.	0·5 c.c.	-0·05 c.c.

Hence this sol follows the general dilution rule that the greater the concentration of the sol the greater is the amount of electrolyte necessary to coagulate the sol.

irrespective of the valency of the precipitating ion. Moreover this sol behaves more or less normally with a mixture of electrolytes.

Negatively charged ferric hydroxide.

This sol, was prepared by the method already described [compare Jour. Phys. Chem. *28*, 305 (1924)].

Concentration of the sol=5·54 grms. Fe_2O_3 per litre.

2 c.c. Sol : Volume=10 c.c.

N Kcl c.c.	$N/_{25}$ $BaCl_2$ c.c.
	0·65
0·5	0·65
1·0	0·65
2·0	0·62
3·0	0·60
5·0	0·55

The sol was very stable and could not be coagulated by N KCl, it could be coagulated by a saturated KCl, but it is readily coagulated by $BaCl_2$ and $AlCl_3$

Negatively charged chromium hydroxide.

This sol was prepared by the method described in part VII of this series [Koll. Zeit. *34*, 262 (1924)].

Concentration of sol=3·62 Cr_2O_3 per litre. 2 c.c. Sol: Volume=10 c.c.

N Kcl	$N/25$ $BaCl_2$
	1·15 c.c.
1·0 c.c.	1·10
3·0	1·05
5·0	1·00

This sol was also very stable and could not be coagulated by N KCl. Strong solutions of KCl coagulated it, whilst it was readily coagulated by $BaCl_2$ and $AlCl_3$.

From the foregoing results, which are of a preliminary nature, we find that the sols are not stabilised towards Ba Cl_2 by the previous addition of KCl and that additive relationship is obtained when negatively charged ferric hydroxide and chromium hydroxide are coagulated by a

mixture of KCl and $BaCl_2$. In other words, the behaviour of these two sols when coagulated by a mixture of electrolyte is normal.

We have shown in other papers that these two sols follow the general dilution rule that the greater the concentration of the sol, the greater is the amount of electrolyte necessary for coagulation irrespective of the valency of the coagulating ion.

Antimony sulphide sol :—

In foregoing papers of this series [Jour. Phys. Chem. 28, 313 (1924); Koll Zeit, (1924)] we have investigated the coagulation of negatively charged antimony sulphide sol by electrolytes under different conditions. In this paper we have investigated the coagulation of the above sol by mixtures of electrolytes and from the following results it will be observed that ionic antagonism is noticeable in the coagulation of this sol by electrolytes. In other words previous addition of small quantities of potassium salts makes this sol stable towards bivalent and trivalent electrolytes.

Concentration of Sb_2S_3 sol (undialysed) = 1·986 grms. per litre, amount of Sb_2S_3 taken = 4 c.c.; Volume = 8 c.c.; Time = $\frac{1}{2}$ hr.

KCl_2 $\frac{N}{4}$	$BaCl_2$ $\frac{N}{125}$ added	$BaCl_2$ $\frac{N}{125}$ Cal	Difference.
1·2	0		
0	0·95		
0·2	0·90	0·79	+0·11
0·4	0·85	0·64	+0·21
0·6	0·55	0·48	+0·07
0·8	0·35	0·32	+0·03

$MgCl_2$ $\frac{N}{100}$	$BaCl_2$ $\frac{N}{125}$ added	$BaCl_2$ $\frac{N}{125}$ Cal	Difference.
1·0	0		
0	0·95		
0·2	0·75	0·76	—0·01
0·4	0·55	0·57	—0·02
0·6	0·45	0·38	+0·07
0·8	0·20	0·19	+0·01

KCl $\frac{N}{4}$	$Al_2(So_4)_3$ $\frac{N}{166 \cdot 7}$ added	$Al_2(So_4)_3$ $\frac{N}{166 \cdot 7}$ Cal.	Difference.
0	1·15	—	
1·15	0	—	
0·2	1·10	—	+0·15
0·4	0·95	0·75	+0·20
0·6	0·70	0·55	+0·15
0·8	0·50	0·35	+0·15

M_gCl_2 $\frac{N}{100}$	$Al_2(So_4)_3$ $\frac{N}{166 \cdot 7}$ added	$Al_2(So_4)_3$ Cal.	Difference.
1·0	·0		
0	1·10		
0·1	1·0	1·0	+0·0
0·4	0·75	0·66	+0·09
0·7	0·40	0·33	+0·07

We have also determined the adsorption of both Ba and K ions when antimony sulphide is coagulated by a mixture of barium chloride and potassium chloride.

Amount of sol taken=75 c.c. containing 0·1490 grm of Sb_2S_3 ; Volume=100 c.c.

Amount of potassium ion already present as K_2So_4 due to the presence of potassium tartrate=0·0795 grm.

Mixture added to 75 c.c. sol.			Amount of cations present as sulphates.	Amount remaining as sulphates.	Adsorption of cations as sulphate.	Adsorption in milli-equivalents.
c.c. N/125 $BaCl_2$	c.c. N/4 KCl.	c.c H_2O				
15	--	10	0·0140 grm Ba So_4	0·0062 grm Ba So_4	0·0078 grm Ba So_4	0·0668 Ba
--	16	9	0·4279 grm K_2So_4	0·4055 grm K_2So_4	0·0224 grm K_2So_4	0·2571 K
10	8	7	0·0095 Ba So_4	0·0060 Ba So_4	0·0035	0·0299 Ba
			0·2537 K_2So_4	0·2438 K_2So_4	0·0099	0·1137 K

From the above experiments on $Sb_2 S_3$ sol we find that the adsorption of barium ion is decreased to the extent of 55% by the presence of potassium ion below the precipitation concentration of the chloride. We have also observed that the adsorption of potassium ion by antimony sulphide is also decreased by the presence of barium ion.

A very interesting fact will be noticed that the sum of the adsorption of potassium and barium ions expressed as equivalents by $Sb_2 S_3$ is greater than the adsorption of barium ion by $Sb_2 S_3$ when coagulated by $BaCl_2$ alone but less than the adsorption of K° ion when coagulated by only KCl.

These results are in entire agreement with the interpretation of the Schulze-Hardy Law from the adsorption point of view already advanced [Dhar, Sen and Ghosh Jour. Phys. Chem. *28*, 457, (1924)]. It was enunciated that an ion which has a high precipitation value (a small coagulating power) is more adsorbed than an ion with a high coagulating power. In other words univalent ions are more adsorbed than bivalent ones. In the case when Sb_2S_3 is coagulated by electrolytes potassium ion is more adsorbed than barium ion and from a mixture of potassium and barium chlorides the sum of the adsorption of barium and potassium expressed in equivalents is less than the adsorption of potassium when coagulated by KCl alone and greater than that of barium when coagulated by only $BaCl_2$.

Mastic sol :—

The sol was prepared by dissolving a known amount of mastic in alcohol and then dropping it in a known volume of water. It has been observed that small quantities of alcohol present in the sol does not effect much in its coagulation by electrolytes.

Concentration of mastic sol=1·2528 grm per litre.

Amount of sol taken each time = 4 c.c. Total volume = 8c.c.; Time = $\frac{1}{2}$ hr.

KCl $\frac{N}{8}$ added	$BaCl_2$ $\frac{N}{25}$ added	$BaCl_2$ $\frac{N}{25}$ calculated	Difference.
0	1·55 c.c.		
1·7 c.c.	0		
0·5 ,,	1·15	1·10	+0·05
0·7 ,,	1·00	0·91	+0·09
0·9 ,,	0·85	0·73	+0·12
1·2 ,,	0·50	0·45	+0·05

KCl $\frac{N}{8}$ added	$Al_2(So_4)_3$ $\frac{N}{2,000}$ added	$Al_2(So_4)_3$ $\frac{N}{2,000}$ calculated.	Difference.
0	1·50 c.c.		
1·70 c.c.	0		
0·10	1·45	1·40	+0·05
0·70	0·95	0·85	+0·10
0·90	0·75	0·68	+0·07
1·20	0·50	0·45	+0·05

Effect of dilution.

Sol A = 4 c.c. sol of the original sol made up to 8 c.c.

Electrolyte	Sol A	Sol $\frac{A}{4}$
KCl $\frac{N}{8}$	1·70 c.c.	>2·5 c.c.
$BaCl_2$ $\frac{N}{25}$	1·55 ,,	1·85 ,,
$Al_3(So_4)_3$ $\frac{N}{2,000}$	1·50 ,,	1·05 ,,

From the experimental results on mastic sol which is negatively charged it will be observed that the sol is abnormal with a mixture of electrolytes and does not follow the dilution rule that the greater the concentration of the sol the greater the amount of electrolyte necessary for coagulation with monovalent and bivalent cations [Compare Neisser and Friedemann Munchen M Wochenster *51*, 827 (1904)].

It will be evident from the foregoing tables on the coagulation of mastic by $BaCl_2$ that the coagulating power of $BaCl_2$ is not preponderatingly greater than that

of KCl. The coagulating power of $BaCl_2$ on mastic is about 7 times greater than that of KCl. In the case of other negatively charged sols the coagulating power of $BaCl_2$ is about 50 times greater than that of KCl.

Consequently the sol is likely to adsorb appreciable quantities of chlorine ions from KCl or from $BaCl_2$. Therefore it seems resonable to expect that in the coagulation of this sol by KCl of $BaCl_2$ the ratio of the adsorption of positive to negative ion is not much greater than unity and the ratio is likely to decrease as the sol is diluted, that is why more KCl or $BaCl_2$ is necessary to coagulate a dilute sol than a concentrated one.

We have proved that negatively charged stannic hydroxide, ferric hydroxide and chromium hydroxide follow the general rule that the greater the concentration of a sol, the greater the amount of electrolyte necessary for its coagulation. We have also shown that when these sols are coagulated by a mixture of electrolytes, the coagulating power of the mixed electrolytes is an additive function of the coagulating powers of the individual electrolytes. In other words towards mixed electrolytes the behaviour of negatively charged stannic hydroxide, ferric hydroxide and chromium hydroxide may be said to be normal.

Similar results have been obtained by Weiser (loc. cit) with a mixture of electrolytes towards stannic hydroxide sol. Recently Freundlich and Scholz (loc. cit) have shown that with colloidal gold and Weimarn's sulphur sol the action of the precipitating cations showed an additive relationship, while the precipitating action was not additive with arsenious sulphide sol and Oden's sulphur sol particularly with mixtures of ions having widely varying precipitating powers. Very recently Weiser has shown that the behaviour with a mixture of electrolytes of positively charged chromium hydroxide sol is normal; in other words, an additive relationship is observed in the coagulation of

positively charged chromium hydroxide sol by mixtures of ions having widely different precipitating powers. Similarly more or less additive relationship was observed with ferric hydroxide by Weiser. Our results with mastic sol show that this sol is abnormal. Consequently sols can be divided into two distinct classes one of which is normal whilst the other class is abnormal as far as their behaviour with mixed electrolyte is concerned, thus

Abnormal	Normal
AS_2S_3	$Cr(OH)_3$ positive
Sb_2S_3	$Fe(OH)_3$,,
Mastic	$Sn(OH)_4$ negative
S (Oden)	Au (Donau)
	S (Weimarn)
	$Fe(OH)_3$ (negative)
	$Cr(OH)_3$ (,,

From the above table will be seen that $Cr(OH)_3$ both positive and negative, $Fe(OH)_3$ both positive and negative, negatively charged $Sn(OH)_4$, Weimarn's S sol and gold sol show additive relationship when coagulated with widely varying coagulating power. It must be observed that $Fe(OH)_3$ both positive and negative $Cr(OH)_3$ both negative and positive $Sn(OH)_4$ negative follow the general dilution rule that the greater the concentration of the sol the gratear the amount of electrolyte necessary for coagulation. On the other hand As_2S_3, Sb_2S_3, mastic, sulphur sol (Odèn) do not show additive relationship in their coagulation by a mixture of electolytes and these very sols do not follow the general dilution rule that the greater the concentration of a sol the greater the amount of electrolyte necessary for coagulation. Consequently we were led to the conclusion that those sols which follow the general dilution rule that the greater the concentration of the sol the greater is the amount of electrolyte necessary for coagulation, should behave normally with a mixture of electrolytes in their coagulation.

In other words there is an intimate connection between the dilution effects of sols and their behaviour with mixture of electrolytes.

Weiser and Nicholas [Jour. Phys. Chem. *25*, 742 (1921)] have shown that Prussian blue on dilution takes less electrolyte for coagulation, in other words this sol follows the general dilution rule.

We expected that Prussiam blue will behave normally when coagulated by a mixture of electrolytes.

Prussian blue sol :—

In order to verify this conclusion we made some preliminary experiments on the coagulation of Prussian blue by mixture of electrolytes. The sol was prepared by washing the precipitate of Prussian blue obtained by treating a solution of $FeCl_3$ with K_4 Fe $(CN)_6$. The sol was dialysed till wash water showed no tests for either $Fe^{\circ\circ\circ}$ or $FeCN_6''''$. We find that Prussian blue does not behave normally as the following experimental results will show:—

Concentration of the sol=7·54 grs. of Prussian blue per litre

KCl $\frac{N}{4}$ added c.c.	$BaCl_2$ $\frac{N}{125}$ added c.c.	$BaCl_2$ $\frac{N}{125}$ Calc. c.c.
1·75 c.c. (coagulated in ½ hour)	...	...
...	2·8 c. c. (coagulated in ½ hour)	...
0·4 c.c.	Did not coagulate with 2·1 c.c. in ½ hour, but showed coagulation with 2·3 c.c.	2·15 c.c. to coagulate in ½hour.
0·8 c.c.	Did not coagulate with 1·70 c.c. on adding 0·2 c.c. to 1·70 c.c. after ½ hour it coagulated.	1·52 c.c. to coagulate in ½ hour.

Having observed the anomaly we were led to study the effect of dilution on the coagulation of Prussian blue

by potassium and barium chlorides. From the results of Weiser and Nicholas (loc. cit) we find that the amount of KCl necessary to coagulate a sol of Prussian blue which is diluted ten times is only 14% less than the amount of KCl necessary to coagulate the sol which is ten times stronger. Whilst in the coagulation of chromium hydroxide sol the amount of KCNS required to coagulate a sol which is ten times diluted in only 1/3 of the amount of KCNS required to coagulate the stronger sol.

From our preliminary experiments we find that a dilute sol of Prussian blue takes more of KCl and less of $BaCl_2$ than the concentrated sol for its coagulation as the following preliminary experiments will show:—

Sol A=1 c.c. of the original sol containing 7·54 grms. of Prussian blue per litre diluted ten times.

Concentration of the sol.	KCl $\frac{N}{4}$	$BaCl_2$ $\frac{N}{125}$
A	Coagulated with 1·75 c.c. in ½ hour.	Coagulated with 2·8 c.c. in ½ hour.
$\frac{A}{10}$	Did not coagulate with 2·1 c.c. in ½ hour.	Coagulated with 2·8 c.c. before ½ hour.

Hence it appears that behaviour of Prussian blue is not normal as shown by Weiser and Nicholas but is abnormal towards its coagulation both by mixed electrolytes and KCl.

These experimental results on the coagulation of Prussian blue strengthen the view that the abnormal dilution effect and abnormal coagulation by mixed electrolytes go hand in hand.

Similarly colloidal gold (Donau's Method) and Weimarn's sulphur which are found to behave normally with mixture of electrolytes should follow the general dilution rule. This is practically all the literature available on the subject. We are trying to extend observations on other sols.

It seems certain that the deviations of the sols from the general dilution rule and from additive relationships towards mixture of electrolytes are based on the same phenomenon. Substances like As_2S_3, Sb_2S_3 etc. adsorb appreciable quantities of ions carrying the same charge and hence they are stabilised on the addition of univalent electrolytes and hence they require greater quantities of bivalent ions for charge neutralisation and coagulation; that is why these sols do not show additive relationship when coagulated by a mixture of electrolytes.

"ACCLIMATIZATION" OF SOLS.

It is an interesting fact that the amount of an electrolyte necessary to coagulate a sol completely is influenced by the rate at which the electrolyte is added. Since an amount of the electrolyte necessary for complete coagulation when the addition is rapid will not cause complete coagulation when the addition is slow, the colloid is said to become acclimatized to the presence of the electrolyte and the phenomenon is called acclimatization.

It should be emphasised that the phenomenon of acclimatization of sols first observed by Freundlich [Zeit. Phys. Chem. *44*, 143 (1903)] can be satisfactorily explained from the point of view of the adsorption of the ion carrying the same charge as the sol. Freundlich observed: "The amount of barium chloride solution containing 9·55 millimoles of $BaCl_2$ per litre, neeessary to precipitate completely in two hours and arsenious sulphide colloid containing 5·752 millimoles of As_2S_3 per litre. The same amount of electrolyte 2c.c. was next added dropwise to the same amount of colloid 20 cc. in 18 hours, 27 days and 45 days respectively. After the addition of each drop the solution was shaken once. Two hours after the addition of the last drop the solutions were filtered and it was found that the filtrate was

still quite cloudy—the cloudiest solution being the one to which the electrolyte was added slowest. In order to precipitate the remainder of the first solution completely 1·5 cc. of the same barium chloride solution was added and after two hours it was clear.

To 20 cc. of a colloid containing 20·45 millimoles of $Fe(OH)_3$ per litre was added 2 cc. of magnesium sulphate solution containing 4·82 millimoles per litre. The addition was made dropwise in the course of eight days, after each addition the flask was shaken once. Although a salt solution of this concentration precipitated the colloid completely after two hours, by this slow addition the solution was not entirely clear two hours after the last drop was added and the filtrate still contained ferric hydroxide. The addition of three drops more of magnesium sulphate solution was sufficient to coagulate the remainder within an hour".

From the foregoing quotations it is evident that with As_2S_3 the phenomenon of acclimatisation is more pronounced than with ferric hydroxide.

Similar results are obtained by Weiser [Jour. Phys. Chem. *25* 399, (1921)] where he observes: "Whereas 1·8 cc. N/50 $K_2C_2O_4$ will certainly cause a complete precipitation in one hour when added all at once, the precipitation was not complete one hour after the addition of the electrolyte by the slow method. By adding 0·1cc. more and allowing to stand one hour more a filtrate clear from colloidal ferric hydroxide was obtained. With arsenious sulphide Weiser obtained the following results. "Precipitation values were determined for strontium chloride and potassium chloride. On rapid addition, 2·05 cc. of N/50 Sr Cl_2 and 2·50 cc. N/2 KCl were necessary to precipitate completely 20 cc. of colloid. The slow addition of the electrolyte in 0·1 cc. portions over a period of approximately 36 hours required 2·50 cc. of $SrCl_2$ and 2·70 of KCl solutions."

Moreover according to the above observation of Freundlich partial precipitation of the sols took place in arsenious sulphide as well as in ferric hydroxide. It has been already noted that As_2S_3, Sb_2S_3 etc. markedly adsorb the ion carrying the same charge; consequently when drops of $BaCl_2$ are added to a sol of As_2S_3 as has been done by Freundlich the sol is appreciably stabilised by the adsorption of chloride ions and so great quantities of $BaCl_2$ are now necessary to coagulate the sol completely. On the other hand ferric hydroxide does not appreciably adsorb the ion carrying the same charge and that is why they are not appreciably stabilised by the addition of a few drops, say of magnesium sulphate; consequently very slow addition of an electrolyte to ferric hydroxide sol produces only a slight increment in the amount necessary for coagulation.

We venture to suggest that sols like As_2S_3, Sb_2S_3, mastic etc., which show abnormal dilution effect and are abnormal in their behaviour towards mixed electrolytes should show this phenomenon of acclimatization more markedly than sols like $Fe(OH)_3$, $Cr(OH)_3$ etc., which follow the general dilution law and are normal towards mixed electrolytes. We are strongly of the opinion that the three phenomena *viz.* (*i*) the abnormality of sols to follow the general dilution rule (2) the abnormality towards mixed electrolytes and (3) the phenomenon of acclimatization are essentially connected and are mainly due to the adsorption of the ion carrying the same charge as the sol.

Weiser has tried to explain the phenomenon of acclimatization from the point of view of the adsorption of ions by the coagulated mass. There is no doubt that the coagulated mass adsorbs electrolytes. Freundlich has observed in his experiments that partial coagulation takes place not only with As_2S_3 but also with $Fe(OH)_3$

and as a matter of fact a little of the precipitating electrolyte is adsorbed by the coagulated As_2S_3 or $Fe(OH)_3$. From our experiments on the adsorption of electrolytes by coagulated substances we find that $Fe(OH)_3$ can adsorb ions appreciably from solutions, and Freundlich [Zeit. Phys. Chem. *73*, 385 (1916)] has shown that coagulated As_2S_3 adsorbs slightly several ions. From our preliminary experiments we are of the opinion that freshly precipitated $Fe(OH)_3$ is a better adsorbent than As_2S_3. Consequently the explanation of the phenomenon of acclimatization advanced by Weiser is certainly incomplete because it cannot explain the occurrence of the phenomenon of acclimatization more markedly with As_2S_3 than with $Fe(OH)_3$. In this respect our explanation stands on a better footing than that of Weiser.

We have made preliminary experiments on the acclimatization of mastic sol towards KCl and of negatively charged ferric hydroxide with $BaCl_2$.

With mastic the following results are obtained:—
When KCl is added very rapidly (the addition of the total volume of electrolyte necessary for coagulation is finished in a few seconds) to 4 c. c. of mastic sol containing 1·2528 grams per litre, the sol requires 1·9 c.c. N/8 KCl for complete coagulation and settling in 18 hours.

When 0·3 c.c. of N/8 KCl is added at the interval of 45 minutes, and the addition is completed in about 6 hours, the sol takes 2·35 c.c. N/8 KCl for complete coagulation and settling in 24 hours.

With negatively charged ferric hydroxide the following results are obtained:—

When $BaCl_2$ is added very rapidly to 2 c.c. of the negatively charged ferric hydroxide sol and the total volume is made to 10 c.c. the sol requires 0·5 c.c. N/25 $BaCl_2$ for complete coagulation and settling in 48 hours.

When $\frac{N}{25}$ $BaCl_2$ is added drop by drop to the same volume of the sol and the addition was carried on for 24 hours, complete coagulation and settling of the sol did not take place in 48 hours, till 0·55 c.c. of $\frac{N}{25}$ $BaCl_2$ was added.

Accordingly, our experiments show that acclimatization is more pronounced with mastic than with negatively charged, ferric hydroxide.

AGEING OF SOLS.

In previous papers (loc. cit) we have investigated the effect of ageing on sols like Sb_2S_3, As_2S_3 etc. We have observed that 5 c.c. of a sol of Sb_2 S_3 when freshly prepared takes 0·85 c.c. of NaCl for complete precipitation, whilst the same amount of the sol kept for 33 days can be precipitated by only 0·70 c.c. of NaCl.

Similarly we have obtained the following results with As_2 S_3 :—

Concentration of As_2S_3 sol = 0·922 grm per litre. Volume = 10 c.c.; Time = 1 hr.

Electrolyte.	Conc.	To coagulate on 15th March, 1924.	10th May, 1924.
KCl	$\frac{N}{2}$	2·0 c.c.	1·8 c.c.
$BaCl_2$	$\frac{N}{50}$	1·30 ,,	1·25 ,,

Moreover in this paper we have repeatedly observed that the effect of ageing is more pronounced when Sb_2 S_3 sol is coagulated by K Cl, NaCl etc., than when the same sol is coagulated by bivalent and trivalent ions.

Consequently we are of the opinion that the effect of ageing will be more noticeable when sols like Sb_2S_3, As_2S_3, mastic etc., are precipitated by univalent cations than when the above sols are coagulated by bivalent and trivalent cations and this phenomenon should be more

pronounced with the above sols than with sols like $Fe(OH)_3$, $Cr(OH)_3$ etc., which hardly adsorb ions carrying the same charge as the sol. It appears that on ageing the electric charge on colloidal particles decreases very little, whilst the capacity for the adsorption of ions carrying the same charge is decreased appreciably and hence the ageing effect is pronounced with Sb_2S_3, As_2S_3 etc., when coagulated by KCl, NaCl etc.

We have frequently observed that the adsorptive power of freshly prepared $Fe(OH)_3$, $Cr(OH)_3$ etc., for negative ions are greatly reduced on ageing. Moreover, we have noted that precipitated $Fe(OH)_3$, $Cr(OH)_3$, etc., prepared about an year ago and kept in contact with water changes colour, the deep brown ferric hydroxide becomes deep red and the green $Cr(OH)_3$ becomes grayish and their chemical activity is greatly decreased. The "aged" precipitates do not dissolve in concentrated H Cl at the ordinary temperature, whilst the freshly precipitated subsances dissolve very readily in HCl.

We are carrying on experiments on ageing with different substances under various conditions.

DISCUSSION.

Let us try to visualise what takes place when positively charged ferric hydroxide sol is coagulated by a mixture of KCl and $K_2C_2O_4$. When a few drops of potassium chloride solution is added to ferric hydroxide sol the chloride ion is attracted by the positively charged sol, and at the same time a very small quantity of potassium ion can also be taken up by the sol. In this case the ratio of the adsorption of chlorine to that of potassium ion is always greater than unity. As the sol is likely to adsorb a little potassium ion also and hence it should be very slightly stabilised. Apparently the effect of the adsorption of potassium ion by ferric

hydroxide would have been that a slight excess to that of the calculated amount of potassium oxalate would have been necessary to coagulate the sol completely. But from experimental results we find that slightly less amount of potassium oxalate is sufficient to coagulate a sol of ferric hydroxide to which KCl has already been added. This is because, as Weiser has pointed out that more of adsorption takes place from dilute solutions than from concentrated ones of the electrolytes. The adsorption of chlorine ion or of oxalate ion is relatively greater at concentrations below their precipitation values. As the sol is precipitated by a mixture of KCl and $K_2C_2O_4$ the concentration of each electrolyte in the mixture will be less than its precipitation concentration and hence the percentage of adsorption of chlorine ion or of oxalate ion will be greater in the mixture than when the sol is coagulated by KCl or by $K_2C_2O_4$ separately [compare Chatterji and Dhar Koll. Zeit. *33*, 18, (1923)]. So that relatively less oxalate ion is necessary to bring the combined adsorption of chloride and oxalate above the critical value necessary for neutralisation and coagulation. This second factor is certainly more predominating and more than counterbalances this very slight stabilisation of the sol due to the slight adsorption of potassium ion, consequently the precipitation values for a mixture of KCl and $K_2C_2O_4$ towards ferric hydroxide are slightly less than additive. Exactly similar explanation can be given in the coagulation of chromium hydroxide, stannic hydroxide negative, negative ferric hydroxide etc. It must be stated clearly that in some cases the precipitation values with a mixture of electrolytes with widely varying precipitation powers may be exactly additive provided there is no complication or the opposing factors to mutually annul each other.

On the other hand with sols like arsenic sulphide, antimony sulphide, mastic etc., we get certain complications.

Weiser has shown with arsenic sulphide and we have shown with antimony sulphide that in presence of monovalent ions like K°, Li° etc., the adsorption of Ba ions by the sulphide sols is greatly decreased. We have also proved experimentally that the adsorption of K ion is also decreased by the presence of Ba°°, consequently the precipitating action of a mixture of electrolytes (KCl and $BaCl_2$) towards Sb_2S_3 sol is not additive but a relatively higher concentration of the bivalent ion is necessary to secure neutralisation of the sulphide sol by adsorption in the presence of K or Li ion.

From our experiments on the adsorption by $Sb_2 S_3$ from a mixture of KCl and $Ba Cl_2$ at the precipitaing value, we find that the presence of KCl decreases the adsorption of Ba ion to an extent of 55% and the adsorption of potassium ion is also depressed to an extent of 56%. Weiser has shewn that at the precipitation concentration of a mixture containing 1/8 the precipitation value of LiCl alone the adsorption of Ba ion is lowered more than 25 per cent; whilst from a mixture containing 1/2 the precipitation value of Li Cl alone the adsorption of Ba is decreased 53%. Weiser has made no experiment on the adsorption of Li ion in presence of Ba ion.

It must be observed that the decrease of adsorption of a bivalent ion in presence of monovalent electrolytes need not be a general phenomenon. Certain cases are actually known, for example in the coagulation of Fe $(OH)_3$ and $Cr(OH)_3$ etc. in which the presence of an excess of chlorine ions does not affect the adsorption of bivalent ions (SO_4'', C_2O_4'') appreciably.

There is another important factor in the precipitation of sols like antimony sulphide, mastic etc. by mixtures of electrolytes. When a few drops of KCl are added to a sol of antimony sulphide the K° ions are adsorbed

and at the same time the adsorption of Cl ions also takes place. If we now precipitate the sol with, say $BaCl_2$ we find that the amount of $BaCl_2$ necessary for the complete coagulation of the sol is greater than the amount of $BaCl_2$ necessary in absence of KCl, consequently we cannot escape the conclusion that in presence of small quantities of KCl the sol of antimony sulphide is made more stable than its absence, and this can only happen by the adsorption of a greater quantity of Cl ion than of potassium ion. In other words when a few drops of KCl are added to a sol of Sb_2S_3 we have to assume that the ratio of adsorption of potassium ion to chlorine ion is less than unity. Now because the sol of Sb_2S_3 can actually be precipitated by KCl we are also forced to the conclusion that at the precipitating concentrations or at higher ones of the electrolytes the ratio of adsorption of K° to Cl' must be greater than unity. In other words the ratio of adsorption of K° to that of Cl goes on increasing as the concentration of the electrolyte becomes greater and greater. From this point of view it seems pretty clear that certain ionic antagonism would also be noticeable in the coagulation of these sulphide or mastic sols even when they are precipitated by a mixture of, say KCl and NH_4Cl. We have assumed that the addition of a few drops of KCl makes the sol of As_2S_3 more stable by the greater amount of adsorption of Cl ions, consequently this stabilised sol should require more of, say NH_4Cl for its coagulation than in the absence of KCl. Unfortunately there is very little experimental work in this line. The only data available is that of Linder and Picton on the coagulation of As_2S_3 by a mixture of HCl and NH_4Cl or HCl and HNO_3, or HNO_3 and K_2SO_4. In all these cases instead of adding only a few drops of the stabilising electrolyte they have at first added 2 c.c. or more of the

electrolyte in question whilst about 4 c.c. is necessary for coagulation. We have already pointed out that the ratio of adsorption by say $As_2 S_3$ of positive ions and negative ions goes on increasing and becomes greater than unity at the precipitating concentration. Consequently when 2 c.c. or more of the stabilising electrolyte is first added the ratio of the adsorption of positive ions to the negative ions may be unity or greater and hence the sol is not at all stabilised by its addition and approximately the calculated amount of the second electrolyte is actually needed for complete coagulation. In order to find out the stabilising influence of the first electrolyte on the sol it is necessary to add only a few drops of the electrolyte and then only the ratio of the adsorption of positive to negative ions would be less than unity and hence the sol would be actually stabilised.

It has been already observed that in presence of $Ba^{\circ\circ}$ ions the adsorption of K° ions by antimony sulphide is appreciably decreased. Consequently in presence of Ba° ion the ratio of the adsorption of K° to that of Cl' can be easily less than unity and hence the sol would appear to be stabilised towards $Ba^{\circ\circ}$ ion if a little of KCl be already present in the sol.

In explaining the phenomenon of acclimatization of a sol we have observed that when only a few drops of barium chloride are added to a sol of arsenious sulphide, the sol may adsorb the Cl' ions along with $Ba^{\circ\circ}$ ions and cansequently when it is precipitated by say $Al(NO_3)_3$ the amount of $Al(NO_3)_3$ taken will be greater than the calculated amount because of the slight stabilisation of the sol produced by the adsorption of a few Cl' ions from $BaCl_2$. This phenomenon will be more marked with mastic when coagulated by $BaCl_2$ and $Al(NO_3)_3$ or $MgCl_2$ and $Al(NO_3)_2$ because the coagulating power of the bivalent ions, $Ba^{\circ\circ}$ and $Mg^{\circ\circ}$ is not preponderingly

greater than that of monovalent ions whilst the precipitating action of trivalent ions is very much greater than that of bivalent ions; consequently in presence of a few drops of $BaCl_2$ mastic will be stabilised by the adsorption of more of Cl′ ions than $Ba^{\circ\circ}$ ions and hence the sol is likely to take up more of $Al(NO_3)_3$ in the presence of a few drops of $BaCl_2$ than in the absence of $BaCl_2$. Experimental work in these lines is in progress in this laboratory.

Finally we have to take into account the decrease of the degree of dissociation of the bivalent electrolytes in presence of an excess of the univalent electrolyte. For example in the coagulation of As_2S_3 or Sb_2S_3 the amount of the monovalent salts required to coagulate a sol is about fifty times greater than the bivalent salt, consequently when these sols are precipitated by mixtures of monovalent and bivalent salts there will always be an excess of the monovalent electrolyte and consequently in its presence the degree of dissociation of bivalent electrolyte will be depressed due to the presence of an excess of the common ion say Cl and consequently more of the bivalent of electrolyte would be necessary for coagulation of colloids.

We have proved that in the coagulation of negative $Cr(OH)_3$, $Fe(OH)_3$, $Sn(OH)_4$ As_2S_3 etc. far greater quantities of KSO_4, $K_4Fe(CN)_6$, potassium citrate etc. are necessary than that of KCl. Similar results were obtained by Linder and Picton, and Weiser with As_2S_3 sol. One reason of this phenomenon is that the bivalent and polyvalent negative ions are more adsorbed by the negative sols than the monovalent ions, the other reason is that the salts with bi and polyvalent ions are less ionised than the salts with univalent ions. Consequently in order to obtain the necessary amount of adsorption for neutralisation and coagulation greater quantities of the electrolytes with polyvalent ions are necessary.

From the results of Weiser we find that when As_2S_3 is coagulated by one electrolyte alone the amounts of electrolytes necessary for coagulating a definite volume of the sol are in the following proportions LiCl : $BaCl_2$ = 50·5 ; LiCl : $MgCl_2$ = 46·6 ; HCl : $MgCl_2$ = 21·8. Consequently the coagulation of As_2S_3 by a mixture of LiCl and $BaCl_2$ should show less deviation from the calculated results than that obtained in the coagulation of the same sol by a mixture of LiCl and $MgCl_2$ because the coagulating power of $MgCl_2$ is not as widely divergent as that of $BaCl_2$ from LiCl. In other words the behaviour of $MgCl_2$ as a coagulating agent towards As_2S_3 is more akin to LiCl than that of $BaCl_2$ to LiCl, hence it is expected that with a mixture of LiCl and $MgCl_2$ in the coagulation of As_2S_3 more of additive relationship should be noticeable than in the coagulation of the same sol by LiCl and $BaCl_2$. As a matter of fact however the results obtained by Weiser are otherwise. The coagulation of As_2S_3 by a mixture of $MgCl_2$ and LiCl shows a greater divergence from the additive relationship than with a mixture of $BaCl_2$ and LiCl in all the data of Weiser (Compare Weiser Jour. Phys. Chem. 1924, *28* p. 239, tables 7 and 8). More or less, similar results have been obtained by Freundlich and Scholz. These results seem to be anomalous. On the other hand the results obtained by Weiser with a mixture of HCl and $MgCl_2$ seem quite normal. The coagulating ratio of $MgCl_2$ to HCl towards As_2S_3 is only 21·8; in other words HCl is a much better coagulating agent than LiCl. We have already emphasised that additive relationship are obtained with mixed electrolytes when the coagulating powers of the electrolytes are of the same order. Consequently in the coagulation of As_2S_3 by a mixture of HCl and $MgCl_2$ we ought to get more of additive relationship than with either LiCl and $BaCl_2$ or LiCl

and $MgCl_2$. The results of Weiser actually confirm the above conclusion.

Weiser has observed "it will be noted that LiCl has a more marked effect on the precipitation value of $MgCl_2$ than of $BaCl_2$. This is exactly one would expect in view of the fact that the adsorption of Mg^{oo} ions is not so great as that of Ba ion as evidenced by the higher precipitation value of $MgCl_2$".

If we accept the above statement of Weiser we should have also observed the marked effect of univalent salts like NH_4Cl in the coagulation of arsenious sulphides by HCl because the amount of adsorption of NH_4 ion and H ion should be more or less identical and should influence each other a great deal; as a matter of fact experimental results show that the precipitation values of NH_4Cl and HCl towards As_2S_3 sol are more or less additive. Similarly it is difficult to understand according to the point of view of Weiser why additive relationships are obtained in the coagulation of As_2S_3 by a mixture of $BaCl_2$ and $MgCl_2$, because the adsorption of Ba^{oo} and of Mg^{oo} would be affected by each other.

In a recent paper Frankfert and Wilkinson [Jour. Phys. Chem. (1924,) *28* p. 651] have studied the adsorption of ions by copper ferrocyanide. They have observed that when copper ferrocyanide is shaken with KCl, KNO_3 or K_2SO_4 the filtrate is acid, whilst the filtrate after shaking with barium nitrate is practically neutral and with aluminium salts the filtrate is alkaline. Some of the results obtained by the above authors seem very peculiar and we are making experiments on the adsorption of substances by copper ferrocyanide.

In the foregoing papers we have proved that MnO_2 which is a negatively charged sol can adsorb the basic part from salt solutions leaving the filtrate acid in all cases, whilst Ba SO_4, $Fe(OH)_3$, $Cr(OH)_3$ etc. which are

positively charged can adsorb the acidic portion of the salt solution leaving the filtrate alkaline. Similarly free silica [Glixelli. Compt. rend *176*, 1714, (1923)] can adsorb basic portion of the salt solution setting free the acid. Moreover, Weiser has shown that when a solution of NaCl is shaken with freshly precipitated $Cu(OH)_2$ alkali is set free. We have also shown that when a sol of mastic is coagulated by KCl, acid is set free. The results of Linder and Picton on the generation of acids by the coagulation of As_2S_3 sol by neutral salts are well known. Similarly, acid is set free when Sb_2S_3 sol is coagulated by KCl, $BaCl_2$ etc. It seems clear therefore that negatively charged sols when coagulated by a salt can set free acid in the filtrate whilst positively charged sols give out alkali in the filtrate. Copper ferrocyanide as ordinarily prepared is negatively charged. But the amount of charge is extremely small as we have repeatedly seen in cataphoretic experiments that the sol move extremely slowly under the influence of electrical force. Hence the sol readily coagulates by the adsorption of a very small quantity of positive ions and at the same time the precipitated substance can also adsorb negative ions because of chemical affinity of the sol for negative ions and can again pass into a negatively charged sol. Moreover the substance is likely to form a positively charged sol by the preferential adsorption of positive ions from an electrolyte. With KCl the sol gets coagulated by the adsorption of K° ions setting free HCl. If potassium ferrocyanide is added to the sol of copper ferrocyanide, at first the sol may be coagulated by the adsorption of positive ions; immediately the neutralised particles will re-adsorb ferrocyanide ions because of the chemcial affinity of the neutralised particles for the ferrocyanide ions setting free alkali. Frankfert and Wilkinson have added alkali to make the aluminium salts neutral. Apparently they have

got in their aluminium solutions negatively charged $Al(OH)_3$ peptised by OH′ ions; consequently when copper ferrocyanide is added to such a mixture the aluminium hydroxide gets coagulated as we have repeatedly observed leaving free the caustic alkali. That is why the above authors have always got alkali in their aluminium salts. If a pure solution of $AlCl_3$ or $Al(NO_3)_3$ is used with copper ferrocyanide free acid is liberated in the coagulation in addition to the acid already existing in the solution due to hydrolyis of aluminium salts. The negatively charged copper ferrocyanide adsorbs aluminium ions from Al salt solutions and sets free an equivalent amount of acids, as there is very little preferential adsorption of Cl or NO_3 ions.

Prussian blue, mastic etc. should behave like copper ferrocyanide because these substances are usually very feebly charged and are of an amphoteric nature.

In a previous paper [Chatterji and Dhar. Koll. Zeit *33*, 18, (1923)] we have investigated the effect of neutural salts on the adsorption of copper and iron from solutions of copper sulphate and ferric chloride by hydrated manganese dioxide. Sodium chloride in normal or double normal concentrations has got very little effect on the adsorption of copper, whilst ammonium chloride has a very small depressing effect. Sodium sulphate in normal solutions has a slight repressing effect. Ammonium sulphate in increasing concentrations decreases adsorption and the same effect is observed with KCl. The effect of an addition of dilute HNO_3 is to depress the adsorption of Ag ion from $AgNO_3$ by hydrated MnO_2.

Substances like canesugar and alcohol which decrease the surface tension of water also decreases the adsorption of silver from $AgNO_3$ by hydrated MnO_2.

Linder and Picton [Jour. Chem. Soc. *66*, 63, (1895)] have shown that when As_2S_3 is precipitated $BaCl_2$

or $SrCl_2$ the metallic radicles are adsorbed by the coagulated substance. If the coagulated sulphide is shaken with KCl or NaCl the adsorbed metal is displaced by Na° or K° and comes out in the solution. We have found that hydrated MnO_2 containing some adsorbed copper losses its copper when shaken with KCl or NaCl or the aqueous solution of any other electrolyte.

It appears therefore that the adsorption by hydrated MnO_2 will depend mainly on two factors (1) the adsorbability of the positive ion and (2) on the concentration of the ion which is going to be adsorbed. From our experiments on hydrated MnO_2 we find that from equivalent solutions of $NaNO_3$ and $AgNO_3$ more of silver is adsorbed than sodium, but adsorbed silver can be displaced by sodium by shaking hydrated MnO_2 containing silver with a large excess of $NaNO_3$. In other words the tendency of silver ions to be adsorbed by MnO_2 in greater quantity than Na ion is counteracted by the large concentration of Na ion. Bearing the above facts in mind the following observation of Freundlich and Scholz would be very interesting. "At the first glance, our observations seem to be different in certain respects from this kind of biological action of electrolytes and from the ionic antagonism observed by Neuschloz [Pfluger's Arch., *181*, 17, 1920)] using Lecithin sol. In both of the latter cases it was frequently observed that the action of univalent cations could be nullified by the addition of divalent cations while with sulphur sol the action of divalent cation was decreased under the influence of univalent cations. This is probably only a superficial difference. The coagulation of the sulphur sol is realized only at such concentrations of univalent cations that small concentrations of divalent cations cannot annul their influence by displacing the adsorption. If we had studied smaller

concentrations of univalent cations, we could have nullified their effect by divalent cations."

These conclusions of Freundlich are in agreement with the experimental observations already cited with hydrated MnO_2, As_2S_3 and Sb_2S_3 sols.

[Lillie: Am. J. Physiol, 10, 433, (1904)] has shown that cilia of the larva of a ringworm Arenicola, is liquefied by a solution containing sodium ion; the addition of a small amount of divalent cation stops this process. We can explain the above fact and other biological salt antagonism in the following way:—The cells in the larva of a ringworm (or any other animal matter) is of an albuminious nature and like albumen either weakly negative or weakly positive or may be neutral. We can assume that the cells are neutral or charged very slightly negatively, in presence of sodium chloride the cells would adsorb Cl' ions due to chemical affinity and would become negatively charged and the larva would pass into liquid state. Now the addition of a little bivalent calcium ion would neutralize negative charge and would re-establish the original conditions of the larva. There is a chemical analogy of this phenomenon of change of mobility due to an adsorption of ion, when sodium hydroxide is gradually added to a fairly concentrated solution of copper sulphate; copper hydroxide which is formed must be positively charged due to the adsorption of Cu ions, and the mixture is very mobile. If the addition of alkali is continued, a certain stage appears when the mobility of the system decreases considerably and a viscous bulky precipitate of cupric hydroxide is obtained. At this stage the whole of the copper is precipitated and the hydroxide is practically neutral. If more alkali is added the mixture becomes again mobile and the copper hydroxide becomes negatively charged due to the adsorption of OH ions and the precipitate become less bulky.

Similar observations can be made in the precipitation of other hydroxides (cf. Sen and Dhar Kolloid Zeit *33*, 193, 1923). Moreover Dhar has shown that ions occupy less volume than undissociated molecules (Dhar, Zeit. Elektro. Chem. *19*, 748 1913).

Ringer [Journal of physiol *4* 29, 222, (1882)] has shown that when the heart of a frog was perfused with a solution of sodium chloride, isotonic with the blood, the beats gradually diminished in extent and ultimately ceased. If calcium chloride were added to the sodium chloride solution when the heart had ceased to beat, the excitability to stimuli returned and was soon followed by spontaneous beats.

In this case also we can assume that the chlorine ion from the sodium chloride solution is first taken up by the cells of the heart and becomes negatively charged. The addition of Ca ions neutralises the charge and makes the heart more or less normal. It seems probable, therefore, that physiological salt antagonism is caused by the preferential adsorption of an univalent ion and its subsequent neutralisation by the bivalent oppositely charged ion or *vice versa.* It must be emphasised that animal cells are of a colloidal nature with large surface behave more or less like amphoteric substances and can readily take up either a feeble positive or a negative charge due to the adsorption of an ion.

Loeb and co-workers, [Pfluger's Arch *97*, 394, (1903); Biochem. Zeit *32*, 308, (1911)] Osterhant [Bot. Gazette *42*, 127, (1906)] and others have shown that a marine Gammarus, Fundulus etc. can only live in a mixture of NaCl, KCl and $CaCl_2$ and sometimes in a mixture of NaCl, KCl, $CaCl_2$ and $MgCl_2$ are necessary.

In order to throw light on physiological salt antagonism, we are investigating the coagulation of various sols and adsorption by mixtures of two and three electrolytes.

Summary.

1. Negatively charged stannic hydroxide has been obtained by the addition of $SnCl_4$ to a dilute solution of caustic soda and subsequent dialysis. The coagulation of the above sol by different electrolytes has been investigated. It has been found that the coagulation follows Schulze-Hardy law with the exception of thorium nitrate.

2. The effect of the change in concentration of the sol on its coagulation by electrolytes has been investigated. It has been observed with this sol that the precipitation value of all electrolytes decreases with the decrease in the concentration of the sol. This result is in agreement with the general rule enunciated in a previous paper that the amount of electrolyte necessary for coagulation decreases with the decrease in the concentration of colloids, irrespective of the valency of the coagulating ion.

3. The influence of the change in concentration of mastic sol towards its coagulation by electrolytes has also been investigated. It is found that the behaviour of this sol towards dilution is abnormal and precipitation value for KCl and $BaCl_2$ increases with the decrease in the concentration of the sol, whilst in the case of $Al_2(SO_4)_3$ the precipitation value decreases with the decreasing concentration of the sol. It has been also observed that the coagulating power of Ba is only about 7 times greater than that of K whilst in the cases of other negatively charged sol the coagulating power of Ba ion is approximately 50 times greater than that of K ion. Hence the sol is likely to adsorb an appreciable quantity of chloride ion from either KCl or $BaCl_2$. This adsorption of ion carrying the same charge as colloid particles can explain the abnormal dilution effect with KCl and $BaCl_2$ and the very low coagulating power of $BaCl_2$ towards mastic.

4. Preliminary experiments on the influence of dilution on the coagulation of Prussian blue by monovalent

KCl and bivalent $BaCl_2$ have been made. It has been found that the sol shows an abnormality towards dilution with KCl and is normal with $BaCl_2$. Weiser and Nicholas (loc. Cit) have, however, obtained normal behaviour with KCl towards dilution of this sol.

5. Coagulation experiments have been made with Sb_2S_3 mastic stannic hydroxide (negative), Prussian blue, ferric-hydroxide (negative) and chromium hydroxide (negative). The behaviour of negatively charged stannic hydroxide, ferric hydroxide and chromium hydroxide is normal; in other words practically additive relationship of precipitation value has been obtained with the above hydroxide sols when precipitated by mixture of electrolytes having widely varying precipitating powers. On the other hand Sb_2S_3, mastic and Prussian blue behave abnormally with mixture of electrolytes; in other words, the precipitation values of mixture of electrolytes of widely varying precipitating powers are always greater than the additive values.

6. The phenomenon of acclimatization can be explained from the point of view that colloid particles can adsorb ions carrying the same charge as the colloid. It follows, therefore, that AS_2S_3, Sb_2S_3, mastic etc. which are known to absorb negative ions markedly should show this phenomenon of acclimitization more markedly than $Fe(OH)_3$ positive and negative, $Cr(OH)_3$ positive and negative etc., which hardly absorb ions carrying the same charge. Experiments of Freundlich and Weiser show that AS_2S_3 sol shows this phenomenon of acclimatization to a greater extent than the positive $Fe(OH)_3$ sol. Our preliminary experiments also show that this phenomenon is very marked with mastic sol than with negatively charged $Fe(OH)_3$.

7. We are of the opinion that the three phenomenon (*a*) abnormality of the sols to follow the general dilution

rule, (*b*) abnormal behaviour towards mitxure of electrolytes and (*c*) the phenomenon of acclimatization are essentially connected and are mainly due to the adsorption of ions carrying the same charge as the sol. Thus As_2S_3, Sb_2S_3, S (Odèn) mastic and Prussian blue behave abnormally towards dilution as well as with a mixture of electrolytes. Moreover, the phenomenon of acclimatization has been found to be more pronounced with As_2S_3, mastic etc., than with $Fe(OH)_3$ negative and positive.

8. It appears that the effect of ageing of sols is more pronounced with sols like Sb_2S_3, As_2S_3 etc. when coagulated by univalent salts like NaCl, KCl etc.

9. When Sb_2S_3 sol is coagulated by a mixture of KCl and $BaCl_2$ the adsorption of $Ba^{\circ\circ}$ ion is decreased to a great extent (55%) due to the presence of K° ion, and the adsorption of K° ion is also decreased due to the presence of Ba ion. The sum of the adsorption of $K^{\cdot}$ and $Ba^{\circ\circ}$ ion expressed as equivalents is greater than the adsorption of Ba ion when coagulated by $BaCl_2$ alone but less than that of K° ion when coagulated by KCl alone. This has been explained from the view that ions of high precipitation value are more adsorbed than ions of low precipitation value.

10. "Ionic antagonism" need not be confined to cases where sols are coagulated by a mixture of electrolytes of widely varying coagulating powers. A certain amount of 'ionic antagonism' should be noticeable when sols like As_2S_3, Sb_2S_3 etc. are coagulated by univalent electrolytes.

11. Certain cases of physiological salt antagonism has been explained from the point of view of adsorption of negative ions by animal cells.

STUDIES IN ADSORPTION XI

Influence of ions carrying the same charge as the sol on the coagulation of sols of (i) Prussian blue and of (ii) positive ferric hydroxide.

S. GHOSH and N. R. DHAR.

In foregoing papers of this series [(Sen, Ganguly and Dhar, Jour. Phys. Chem. *28*, 313, (1924); Dhar, Sen and Ghosh, Jour. Phys. Chem. *28*, 457, (1924); Sen and Dhar, Koll Zeit. *34*, 262, (1924); Ghosh and Dhar, Koll Zeit. *35*, 144, (1924); same journal (1924),], the influence of ions carrying the same charge as the colloid particles on the coagulation of sols has been studied and its importance in the explanation of various phenomena in colloid chemistry has been emphasised. In the previous paper of this series [Jour. Phys. Chem. (1925)] we have arrived at the following conclusions:—

(*i.*) The abnormal dilution effect shown by such sols as As_2S_3, Sb_2S_3, mastic etc., when coagulated by monovalent electrolytes like KCl, LiCl etc., (*viz.*, more of these electrolytes is necessary to coagulate a dilute sol than a concentrated one) has been attributed to the fact that these sols can adsorb the ions carrying the same charge as the colloid particles.

(*ii.*) The abnormal behaviour shown by these sols with mixtures of electrolytes (*viz.*, the precipitation values of mixture of electrolytes of widely varying precipitating powers are greater than the additive values) is also explained from the same point of view, so that a sol is partially stabilised by the adsorption of ions carrying the same charge as the colloid particles,

(*iii.*) The phenomenon of acclimatization has been explained from the point of view that colloidal particles can adsorb ons carrying the same charge as the colloid. It follows therefore that such sols as As_2S_3, Sb_2S_3, mastic etc., which are known to adsorb negative ions show this phenomenon more markedly than $Fe(OH)_3$ positive and negative, $Cr(OH)_3$ positive and negative etc., which hardly adsorb monovalent ions carrying the same charge as that on the sols.

We are of the opinion that the three phenomena (*a*) abnormality of sols to follow the general dilution rule, (*b*) abnormal behaviour with a mixture of electrolytes of widely varying precipitating values, and (*c*) the phenomenon of acclimatization are essentially connected and are mainly due to the adsorption of ions carrying the same charge as the sol. From all the data available from our experiments as well as those of other workers in this line it has been found that those sols, which are normal towards mixed electrolytes also show normal behaviour on dilution. Moreover it has been proved with mastic sol (Ghosh and Dhar, loc. cit) and arsenic trisulphide sol [Freundlich Zeit. Phys. Chem. *44*, 143, (1903); Weiser, Jour. Phys. Chem. *25*, 399, (1921)] which show abnormal behaviour towards dilution when coagulated by KCl, LiCl etc., towards a mixture of electrolytes, and also show the phenomenon of acclimatization more markedly than positively charged ferric hydroxide (Freundlich, loc. cit and Weiser, loc. cit) and negatively charged ferric hydroxide.

From a few preliminary experiments on Prussian blue, we concluded that the sol behaves abnormally towards KCl, LiCl etc., on dilution and is also abnormal towards a mixture of electrolytes. On the other hand, Weiser and Nicholas [Jour. Phys. Chem. *25*, 743, (1921)] have observed that this sol shows a normal behaviour towards KCl on dilution. It will be observed from their data that

the amounts of monovalent electrolyte necessary to coagulate strong and dilute sols are not very different when compared with the amounts of electrolytes like KCl, $KBrO_3$ etc., necessary to coagulate concentrated and dilute sols of positively charged ferric hydroxide, which may be considered as one of the typical normally behaving colloidal solution.

TABLE I

Precipitation of Prussian blue colloid.

Concentration of colloid.	Precipitation values.		
	KCl	$BaCl_2$	$AlCl_3$
100 % (8 grms. per litre)	89·6	4·25	2·200
75 %	87·5	3·33	1·625
50 %	85·4	2·75	1·125
25 %	81·2	2·16	0·500
10 %	77·1	1·67	0·208

TABLE II.

Precipitation of ferric oxide colloid.

Concentration of colloid.	Precipitation values.		
	$KBrO_3$	K_2SO_4	$K_3Fe(CN)_6$
100 % (1·7 grm. per litre)	40·1	0·68	0·57
50 %	34·4	0·41	0·30
25 %	28·0	0·25	0·16
12·5 %	25·0	0·16	0·08

It will be observed that the amount of the monovalent electrolyte KCl necessary to coagulate Prussian blue decreases to about 10% when the sol is diluted 4 times, whilst

the amount of monovalent electrolyte $KBrO_3$ necessary to coagulate positively charged ferric hydroxide decreases to more than 25% for the same dilution.

In this paper we have carefully investigated the dilution effect, the phenomenon of acclimatization, and the action of mixed electrolytes with Prussian blue. We have also investigated the influence of stabilising ions on the coagulation of positively charged ferric hydroxide sol. Moreover, we have also observed the effect of KOH and several non-electrolytes on the coagulation of arsenious and antimony sulphide sols by electrolytes. It is well-known that freshly precipitated ferric hydroxide, chromium hydroxide etc., can be peptised by the specific adsorption of $Fe^{\circ\circ\circ}$, $Cr^{\circ\circ\circ}$, $Al^{\circ\circ\circ}$ ions etc., by the hydroxides from solutions of ferric chloride, chromium chloride, aluminium chloride etc. It seems probable therefore, that the adsorption of these ions should follow the ordinary adsorption laws. Now when $FeCl_3$ is first added in small quantities to a $Fe(OH)_3$ sol the colloid particles, due to chemical affinity, will adsorb some similarly charged $Fe^{\circ\circ\circ}$ ions. The percentage of $Fe^{\circ\circ\circ}$ adsorption is high as the solution of $FeCl_3$ is very dilute, so that the equivalent amount of oppositely charged ions (Cl') has practically no precipitating action. Now as the amount of $FeCl_3$ is gradually increased the adsorption of positively charged ferric ion reaches a saturation limit and the precipitating ion (Cl') which also increases in concentration tends to overcome the peptising effect of $Fe^{\circ\circ\circ}$ ions and coagulates the sol.

If the sol is now diluted say twice the amount of adsorption of $Fe^{\circ\circ\circ}$ ion by the sol is not actually halved; on the other hand, the amount of the adsorption of chlorine ions by the colloidal particles is practically halved, as this adsorption is mainly due to the electrical attraction. Consequently the total effect is that $Fe^{\circ\circ\circ}$ ion shows a greater peptising effect than the precipitating influence of the oppositely

charged chloride ion, when the same amount of ferric chloride is added to a diluted sol of ferric hydroxide than to a concentrated sol. Hence more of $FeCl_3$ is necessary to coagulate the dilute sol than a stronger one. When ferric chloride is added to a sol of ferric hydroxide it will adsorb both the ions, but the chlorine ion is adsorbed more than the ferric ion because the sol is actually coagulated by the electrolyte. It seems very likely that the ratio of the adsorption of negative to that of the positive ion gradually become smaller and smaller and approaches unity and in certain cases, the ratio may be less than unity. That is why more and more $FeCl_3$ is necessary to coagulate a dilute sol of ferric hydroxide than a concentrated one.

Ferric hydroxide has chemical affinity for $Fe^{\circ\circ\circ}$ ions and can readily adsorb them. It is possible that when small quantities of $FeCl_3$ is added to a sol of $Fe(OH)_3$ such that no coagulation takes place, the amount of ferric ion adsorbed is slightly greater than that of chlorine ion and hence the sol becomes more stable towards KCl. This effect will be greatly diminished if the adsorption of ions carrying the same charge as the colloid particles is extremely small or the precipitating effect of the oppositely charged ions is very great. A similar line of argument was advanced in the explanation of the abnormal dilution effect of sols like As_2S_3, Sb_2S_3 etc., towards KCl, LiCl etc., [compare Sen and Dhar (loc cit)]. It is known that As_2S_3, Sb_2S_3 etc., adsorbs appreciable amounts of chloride, nitrate, sulphate ions etc., so that more of monovalent K from KCl is necessary to coagulate a dilute sol than a stronger one, on the other hand the effect is not so marked with electrolytes of bivalent cations like $Ba^{\circ\circ}$, $Mg^{\circ\circ}$ etc., and still so with trivalent cations like $Al^{\circ\circ\circ}$, $La^{\circ\circ\circ}$, $Ce^{\circ\circ\circ}$ etc., where very small quantities of electrolytes bring about the coagulation and the stabilising action of Cl', NO_3', SO_4''

is compensated by the greater precipitating action of $Ba^{\circ\circ}$, $Al^{\circ\circ\circ}$ etc., than monovalent K°, Li° etc. Consequently it seems probable that when coagulation of sols is effected by electrolytes of which both the ions can be adsorbed by the sols, we are likely to get (*i*) abnormal dilution effect, (*ii*) abnormal behaviour towards a mixture of electrolytes and (*iii*) phenomenon of acclimatization.

In the following experiments we will show that $Fe(OH)_3$ sol which behaves normally in its coagulation by KCl, $KBrO_3$ etc., is abnormal when coagulated by $FeCl_3$, $Al(NO_3)_3$ etc., because from these electrolytes both the positive and the negative ions are appreciably adsorbed and the ratio of the adsorption of negative ion to that of positive ion decreases with the decreasing concentration of the sol; just as in the coagulation of As_2S_3, Sb_2S_3, mastic etc., by KCl, LiCl etc., the ratio of adsorption of positive to negative ion decreases with the decreasing concentration of the sol.

On the other hand, sols like As_2S_3, Sb_2S_3 etc., which behave abnormally on dilution when coagulated by KCl, NaCl etc., should behave normally when coagulated by an electrolyte of which mainly the positive ion is adsorbed by the sol. Our results on the coagulation of As_2S_3 sol by $AgNO_3$ prove that the coagulation of this sol follows the general dilution rule, when coagulated by $AgNO_3$.

EXPERIMENTAL.

Prussian blue :—

The sol is prepared by precipitating Prussian blue from a solution of $FeCl_3$ by potassium ferrocyanide and washing the precipitated mass with distilled water. The sol is obtained as a filtrate and can be made a concentrated one.

The sol is dialysed through a parchment paper for seven days when it is free from ferrocyanide. The sol made up to 5 c.c. in clean tubes, is mixed with the electrolyte made up to 5 c.c. in another tube and kept for two hours when complete coagulation and clearing at the top of the mixture are observed. A series of experiment were carried out by the addition of electrolytes near the precipitation value and the exact precipitation value is found out with great care. It will be very interesting to note that this sol even after coagulation can again pass to the colloidal state on dilution and is extremely sensitive to shaking. With special care coagulation and complete clearing at the top of the mixture in a definite time can be reproduced with the same concentration of the precipitating electrolyte and the sol.

TABLE III.

Strength of Prussian blue sol = 2·88 grms per litre; sol A = 1 c.c. of the sol made upto 10 c.c.

Volume = 10 c.c. ; Time = 2 hrs.

Conc. of the sol.	KCl $\frac{N}{4}$	$BaCl_2$ $\frac{N}{50}$	$Al(NO_3)_3$ $\frac{N}{400}$
A	1·70	1·05	0·90
$\frac{A}{2}$	1·80	0·95	0·50
$\frac{A}{10}$	2·00	0·80	0·20

In order to be absolutely certain that the results obtained in the previous table are reproducible and valid for all samples of Prussian blue sols, a fresh sol of Prussian blue was prepared. This sol was dialysed for a week and freed from electrolytes. The sol was coagulated by KCl at two different dilutions and the following results were obtained.

TABLE IV.

Strength of the Prussian blue sol = 2·76 grms per litre; sol A = 1 c.c. of the original sol made upto 10 c.c. Volume = 10 c.c.; Time = 20 hours.

Concentration of the sol.	Amount of KCl $\frac{N}{4}$ requird to coagulate.
A	2·30 c.c.
$\frac{A}{2}$	2·40 c.c.

Hence with this sample of the sol also we find that the diluted sol takes more of KCl for coagulation than a concentrated one.

Weiser and Nicholas (loc. cit) have reported that the sol of Prussian blue prepared by them contained free potassium ferrocyanide. We are trying to find out whether the difference between our results and those obtained by the above authors can be attributed to free $K_4Fe(Cn)_6$.

In the following tables the results are given as obtained when Prussian blue sol is coagulated by a mixture of various electrolytes.

TABLE V.

Coagulation of Prussian blue sol by a mixture of KCl and $BaCl_2$.

Volume = 10 c.c. Time = 2 hours. Amount of sol taken each time = 1 c.c.

KCl $\frac{N}{4}$ added c.c.	$BaCl_2$ $\frac{N}{50}$ added c.c.	$BaCl_2$ $\frac{N}{50}$ Calculated c.c.	Difference.	Percentage of the difference.
0	1·05			
1·8	0			
0·1	1·25	0·98	+0·27	28
0·3	1·35	0·88	+0·47	54
0·6	1·30	0·70	+0·60	86
0·8	1·15	0·58	+0·57	98
1·0	0·80	0·47	+0·33	70
1·40	0·45	0·23	+0·22	96

TABLE VI.

Coagulation of Prussian blue sol by a mixture of KCl and HCl.

HCl $\frac{N}{5}$ added c.c.	KCl $\frac{N}{4}$ added c.c.	KCl $\frac{N}{4}$ Calculated c.c.	Difference.	Percentage of the difference.
0	1·80			
1·9	0			
0·1	1·2	1·71	—0·51	30
0·5	0·75	1·33	—0·58	43
1·0	0·50	0·85	—0·35	41
1·7	0·10	0·19	—0·09	46

TABLE VII.

Coagulation of Prussian blue sol by a mixture of KNO_3 and HNO_3.

HNO_3 $\frac{N}{5}$ added c.c.	KNO_3 $\frac{N}{4}$ added c.c.	KNO_3 $\frac{N}{4}$ Calculated c.c.	Difference.	Percentage of the difference.
0	2·00			
1·9	0			
0·1	1·3	1·89	—0·59	31
0·5	0·75	1·37	—0·62	45

TABLE VIII.

Coagulation of Prussian blue sol by a mixture of KCl and KNO_3.

KNO_3 $\frac{N}{4}$ added c.c.	KCl. $\frac{N}{4}$ added c.c.	KCl. $\frac{N}{4}$ Calculated c.c.	Difference.	Percentage of the difference.
0	1·8			
2·0	0			
0·5	1·45	1·35	+0·10	7
1·0	0·9	0·9	+0·0	0
1·5	0·4	0·45	—0·05	11
1·9	0·10	0·09	+0·01	11

TABLE IX.

Coagulation of Prussian blue sol by a mixture of $BaCl_2$ and $MgCl_2$.

$MgCl_2$ $\frac{N}{50}$ added c.c.	$BaCl_2$ $\frac{N}{50}$ added c.c.	$BaCl_2$ $\frac{N}{50}$ Calculated c.c.	Difference.	Percentage of the difference.
0	1·05			
2·70	0			
0·2	1·00	0·97	+0·03	3
0·8	0·8	0·74	+0·06	8
1·4	0·6	0·51	+0·09	17

TABLE X.

Coagulation of Prussian blue sol by a mixture of $BaCl_2$ and $Al(NO_3)_3$.

$BaCl_2$ $\frac{N}{50}$ added c.c.	$Al(NO_3)_3$ $\frac{N}{100}$ added c.c.	$Al(NO_3)_3$ $\frac{N}{400}$ Calculated c.c.	Difference.	Percentage of the difference.
0	0·90			
1·05	0			
0·10	0·90	0·82	+0·08	10
0·30	0·75	0·64	+0·11	17
0·50	0·55	0·47	+0·08	17
0·70	0·30	0·25	+0·05	20

Acclimatization of Prussian blue colloid and positively charged ferric hydroxide sol.

The following results were obtained on the acclimatization of Prussian blue colloid towards KCl and $BaCl_2$:—

When 1·80 c.c. $\frac{N}{4}$ KCl is added to a sol of Prussian blue (1 c.c. of the original sol made up to 8 c.c.) all at once complete coagulation occurs within 2 hours. The precipitation was, however, not complete in 2 hours after adding the electrolyte, if 1·8 c.c. $\frac{N}{4}$KCl is added to the same amount

of the sol in 70 hours, 0·2 c.c. of the electrolyte being added at a time. By adding 0·4 c.c. $\frac{N}{4}$ KCl more and allowing the sol to stand undisturbed for 2 hours, the complete coagulation is effected.

When 1·05 c.c. $\frac{N}{50}$ $BaCl_2$ is added all at once the complete coagulation of the colloid (1 c.c. of the sol made upto 9 c.c.) occurs within 2 hours. If, however, the addition is slow and 1 c.c. $\frac{N}{50}$ $BaCl_2$ is added in 70 hours, 0·1 c.c. of the electrolyte being added at a time, complete coagulation does not occur in 2 hours after the last addition of the electrolyte. On adding 0·1 c.c. $\frac{N}{50}$ $BaCl_2$ more and allowing the colloid to stand for 2 hours complete precipitation is observed.

The following results were obtained on the acclimatization of positively charged ferric hydroxide sol by $Al(NO_3)_3$ and $KBrO_3$:—

When 5·0 c.c. of N $Al(NO_3)_3$ is added all at once to 7 c.c. of ferric hydroxide sol containing 1·034 grms. of Fe_2O_3 per litre complete coagulation occurs after 24 hours, whilst the same amount of the sol requires 5·4 c.c. to completely coagulate the sol in 24 hours after the last addition of the electrolyte, when the addition is effected in 120 hours, 0·3 c.c. of the electrolyte being added at a time.

When the sol of ferric hydroxide is coagulated by $KBrO_3$ $\frac{N}{5}$, 7 c.c. of $Fe(OH)_3$ containing 1·034 grms. of Fe_2O_3 per litre takes 2·1 c.c. of the electrolyte to completely precipitate in 24 hours. It has, however, been observed that if the addition of the electrolyte is effected in 72 hours, complete coagulation occurs with 2·1 c.c. $\frac{N}{5}$ $KBrO_3$.

It will be seen from the results of the experiments on acclimatization that the phenomenon is marked with $Fe(OH)_3$ sol towards $Al(NO_3)_3$, whilst it is not at all observed towards $KBrO_3$.

Effect of dilution on the coagulation of As_2S_3 sol with $AgNO_3$.

The arsenic sulphide sol is prepared by the method already given in a previous communication (see Ghosh and Dhar, loc. cit). The following table gives the results.

TABLE XI

Sol A = 0·41 grms. of As_2S_3 per litre. Volume = 10 c.c. Immediate coagulation is observed.

Concentration of the sol.	Amt. of N/4·88 $AgNO_3$ to coagulate.
A	0·70 c.c.
A/4	0·20 c.c.
A/10	0·10 c.c.

It has been already remarked in this paper that As_2S_3 requires more of univalent salts like KCl, NaCl etc., to coagulate a dilute sol than a concentrated one. It will be interesting to observe from the above table that the amount of $AgNO_3$ required for complete coagulation decreases with the decreasing concentration of the sol.

Freundlich [Kapillarchemie page 576, (1922)] has shown that univalent organic cations of morphine hydrochloride, aniline hydrochloride behave as far better coagulating agents than KCl, LiCl etc. in the coagulation

of As_2S_3 sol. Many of these organic cations are also highly adsorbed and it is expected that these will behave normally on dilution towards the coagulation of As_2S_3 sol. Experiments in this line are in progress in this laboratory.

Ferric hydroxide sol (positive).

The sol was prepared after the manner of Krecke [Jour. Prakt. Chem. *3*, 286 (1871)] by the gradual addition of a concentrated solution of ferric chloride to a large volume of boiling water which was kept well stirred. The sol did not give any coloration with potassium ferrocyanide, but contains hydrochloric acid, which is removed by dialysis lasting 9 days. The following table gives the result on the effect of dilution of the ferric hydroxide sol when coagulated by $Al(NO_3)_3$, $FeCl_3$ and KCl.

TABLE XII

Strength of the sol=3·62 grms. of Fe_2O_3 per litre.
Sol A=2 c.c. of the original sol made upto 10 c.c.; volume=10 c.c. Immediate turbidity is observed.

Concentration of the sol.	Amount necessary to coagulate.		
	N KCl	N $Al(NO_3)_3$	$\frac{3N}{2}$ $FeCl_3$
A	1·10 c.c.	2·30 c.c.	3·2 c.c.
A/4	0·90 c.c.	2·50 c.c.	3·3 c.c.
A/10	0·70 c.c.	2·70 c.c.	3·4 c.c.

The following table gives the result when ferric hydroxide sol is coagulated by a mixture of $Al(NO_3)_3$ and K_2SO_4.

TABLE XIII.

Amount of sol taken each time = 2 c.c; volume = 10 c.c. Immediate turbidity is observed.

$Al(NO_3)_3$ N added c.c.	K_2SO_4 N/400 added. c.c.	K_2SO_4 N/400 Calculated c.c.	Difference.	Percentage of the difference.
0	1·45			
2·3	0			
0·2	1·80	1·32	0·48	36
0·5	1·75	1·13	0·62	57
0·8	1·65	0·95	0·70	74
1·6	1·35	0·44	0·91	207

Antimony sulphide and Arsenious sulphide sols.

In the following tables results are given as obtained when Sb_2S_3 and As_2S_3 sols are coagulated by electrolytes in presence of KOH and various non-electrolytes. The sulphide sols are prepared by the method already described in previous communications.

TABLE XIV.

Coagulation of Sb_2S_3 sol in presence of KOH. Strength of the Sb_2S_3 sol = 3·7157 grs. pot., antimony tartrate per litre. Volume = 8 c.c.; amount of sol taken = 4 c.c.; Time = $\frac{1}{2}$ hour.

Amount of KOH N/7·35 added cc.	Amount of electrolyte to coagulate.		
	KCl $\frac{N}{4}$ c.c.	$BaCl_2$ N/125 c.c.	$Al_2(SO_4)_3$ N/166·6 c.c.
0	1·25	0·95	1·10
0·1 (Antimony not present in the filtrate.)	1·25	1·10	did not coagulate with 1·10 c.c.
0·5 (Antimony present in the filtrate)	1·35	0·85	Do.

Table XV.

Coagulation of Sb_2S_3 sol in presence of cane sugar. Another sample of Sb_2S_3 sol of the same concentration as in the previous table is used here.

Cane sugar $\frac{M}{10}$ added c.c.	Amount necessary to coagulate.		
	KCl $\frac{N}{4}$ c.c.	HCl $\frac{N}{5}$ c.c.	$BaCl_2$ $\frac{N}{125}$ c.c.
0	1·20	1·30	0·95
1	1·10	1·30	0·90
2	1·10	1·30	——

Table XVI.

Coagulation of Sb_2S_3 sol in presence of urea.

Urea M added c.c.	Amount necessary to coagulate.	
	KCl $\frac{N}{4}$ c.c.	$BaCl_2$ N/125 c.c.
0	1·10 *	0·95
2	1·00	0·85

*The sol has turned slightly unstable on standing for about 15 days.

Table XVII.

Coagulation of Sb_2S_3 sol in presence of ethyl alcohol.

Ethyl alcohol 98 % added. c.c.	Amount necessary to coagulate.		
	KCl N/4 c.c.	$BaCl_2$ N/125 c.c.	$Al_2(SO_4)_3$ N/166·6 c.c.
0	1·20	0·95	1·15
0·5	1·20	1·00	1·25
1·0		1·05	

TABLE XVIII.

Coagulation of Sb_2S_3 sol in presence of propyl alcohol.

Propyl alcohol added c.c.	Amount necessary to coagulate.		
	KCl N/4 c.c.	$BaCl_2$ N/125 c.c.	$Al_2(SO_4)_3$ $\frac{N}{166.6}$ c.c.
0	1·25	0·95	1·15
1	1·20	1·10	1·70

TABLE XIX

Strength of As_2S_3 Sol = 3·134 grs. per litre.

Amount of sol taken each time = 4 c.c.; volume = 8 c.c.; Time = ½ hour. Coagulation of As_2S_3 sol in presence of cane sugar.

Cane sugar $\frac{M}{10}$ added c.c.	Amount necessary to coagulate.	
	KCl $\frac{N}{2}$ c.c.	Ba Cl_2 $\frac{N}{125}$ c.c
0	1·40	1·75
1·0	1·30	1·70

TABLE XX

Coagulation of As_2S_3 sol in presence of urea.

Urea M added c.c.	Amount necessary to coagulate.	
	KCl $\frac{N}{2}$ c.c.	$BaCl_2$ $\frac{N}{125}$ c.c.
0	1·40	1·75
2	1·40	1·60

TABLE XXI

Coagulation of As_2S_3 sol in presence of ethyl alcohol.

Ethyl alcohol 98% added c.c.	Amount necessary to coagulation. KCl $\frac{N}{2}$ c.c.	BaCl$_2$ $\frac{N}{125}$ c.c.
0	1·40	1·75
0·5	1·40	2·00
1·0	1·50	2·20

Coagulation of $Fe(OH)_3$ sol by barium sulphate.

It has been observed in a previous paper (see Ghosh and Dhar, loc. cit) that $Fe(OH)_3$ sol can be coagulated by freshly precipitated $BaSO_4$. The following table gives the result of the effect of dilution on the coagulation of $Fe(OH)_3$ sol by $BaSO_4$.

Sol A = 0·226 grms. Fe_2O_3 per litre.

TABLE XXII

Amount of sol taken = 8 c.c.

Concentration of the sol.	Amount of $BaSO_4$ to coagulate in grm.
A	0·8648 grm.
$\frac{A}{2}$	0·5596 ,,
$\frac{A}{5}$	0·366$\overline{4}$,,

It will be seen from the above table that the amount of $BaSO_4$ required to coagulate $Fe(OH)_3$ decreases with the decreasing concentration of the sol.

Coagulation of arsenious sulphide by barium sulphate.

In a previous paper (Ghosh and Dhar, loc. cit) we have determined the coagulation of sulphides of arsenic and antimony by freshly precipitated $BaSO_4$ free from electrolytes. In this paper we have investigated the influence of the change of concentration on the coagulation of As_2S_3 sol by $BaSO_4$ and the following results were obtained.

TABLE XXIII

Original concentration of As_2S_3 sol $= 0{\cdot}81$ grm. per litre. Sol $A = 0{\cdot}5$ c.c. made up to 8 c.c.; Vol $= 8$ c.c.; Time $= \frac{1}{2}$ hour.

Concentration of the sol.	Amount of $BaSO_4$ in grams.
A	0·4578
$\frac{A}{2}$	0·2645
$\frac{A}{4}$	0·1323

These results prove conclusively that in the coagulation of As_2S_3 sol by $BaSO_4$, the greater the concentration of the sol, the greater is the amount of $BaSO_4$ necessary for coagulation. It will be evident from the curve that the amount of $BaSO_4$ necessary to coagulate As_2S_3, $Fe(OH)_3$ varies practically directly with the concentration of As_2S_3, and $Fe(OH)_3$ sols.

Coagulation of arsenious sulphide by positively charged $Fe(OH)_3$ sol.

Moreover we have determined the coagulation of As_2S_3 sol by a positively charged ferric hydroxide sol and the following results were obtained:—

Opposite to p. 352

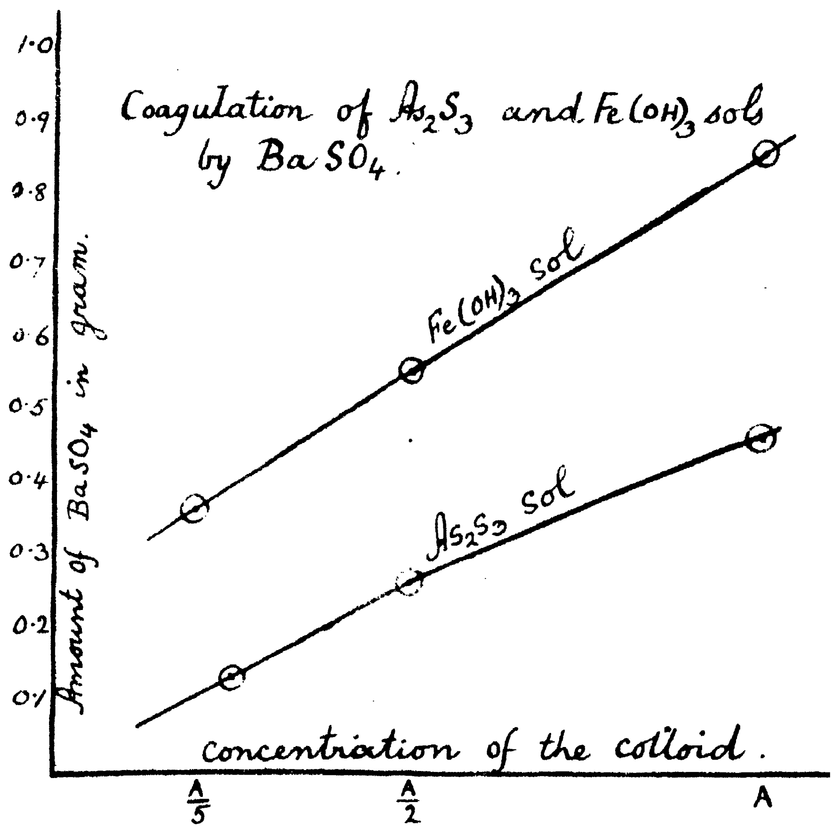


TABLE XXIV

Strength of As_2S_3 sol = 0·81 grm. per litre.
Strength of $Fe(OH)_3$ sol = 3·62 grms. per litre.
Sol A = 0·5 c.c. As_2S_3 sol made up to 8 c.c.
Immediate coagulation is observed.

Concentration of sol.	Amount of Fe $(OH)_3$ sol to coagulate.
2 A	0·55 c.c.
A	0·35 c.c.
$\frac{A}{2}$	0·20 c.c.

From the above results it is clear that in this case also the greater the concentratoin of As_2S_3 sol the greater is the amount of positively charged $Fe(OH)_3$ colloid necessary for coagulation.

Consequently the coagulation of As_2S_3 sol by barium sulphate and by positively charged ferric hydroxide is normal towards the dilution, whilst this sol behaves abnormally towards dilution when coagulated by KCl, LiCl etc.

DISCUSSION (A)

These results of the coagulation of Prussian blue confirm our preliminary results already published in the previous paper of this series. In other words this sol behaves abnormally towards dilution and towards a mixture of electrolytes. The behaviour of this sol is exactly like that of As_2S_3 sol ; just as a dilute sol of arsenic sulphide takes more electrolyte of the type KCl, LiCl, etc., for coagulation than concentrated sols, similarly a dilute sol of Prussian blue takes more KCl for coagulation than a concentrated sol. Our results do not agree with

those obtained by Weiser and Nicholas (loc. cit) who observed normal behaviour on dilution in the coagulation of Prussian blue. The coagulation of Prussian blue by mixture of electrolytes also behave exactly in the same way as the coagulation of arsenious sulphide. Some very peculiar results have been obtained in the coagulation of Prussian blue by mixture of KCl and HCl, and KNO_3 and HNO_3. From our experiments we find that the precipitation values are not additive. In presence of HCl the amount of KCl necessary to coagulate Prussian blue is much less than the calculated amount of KCl necessary for coagulation. Exactly, similar results have been obtained by us in the coagulation of Prussian blue by a mixture of HNO_3 and KNO_3. On consulting the literature we find that more or less similar results have been obtained by Linder and Picton [Jour. Chem. soc. *67*, 63, (1895)] in the coagulation of As_2S_3 sol by mixture of electrolytes. Their results are given in the following tables:—

TABLE XXV

Salt A.	Volume A.	Salt B.	Volume B to complete coagulation.	Calculated volume of B.	Difference
NH_4Cl	4·90	HCl	4·20		
NH_4Cl	2·00	HCl	2·40	2·50	−0·10
		HNO_3	4·10		
HCl	2·35	HNO_3	1·97	1·80	+0·17
HCl	2·60	NH_4Cl	1·75	1·85	−0·10
		K_2SO_4	4·40		
HNO_3	2·00	K_2SO_4	1·95	2·25	−0·30

It will be seen that in presence of HCl quantities of NH_4Cl smaller than the calculated amounts are necessary to coagulate the sol. Similarly in presence of HNO_3 smaller quantities of K_2SO_4 than the calculated amounts are required to precipitate the sol, whilst more or less additive amounts of HNO_3 and HCl coagulate the sol.

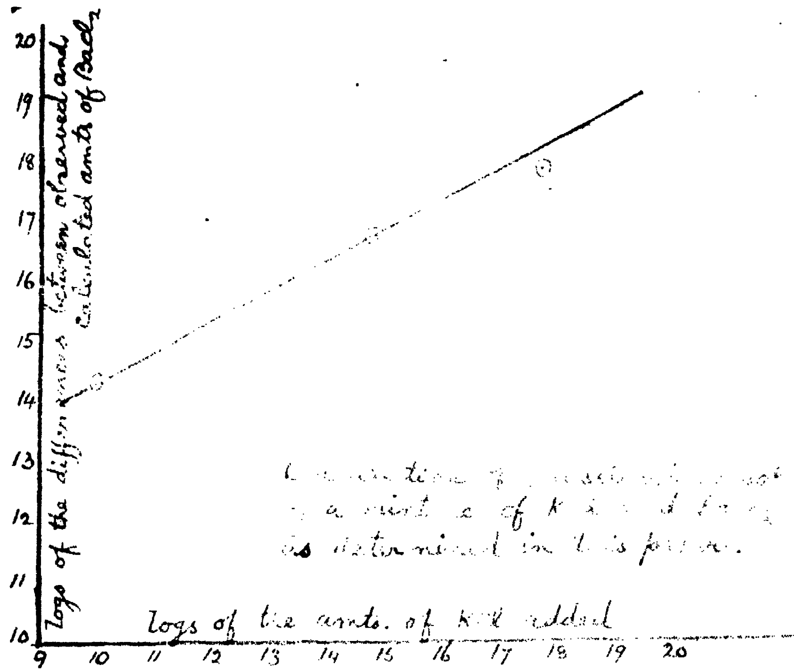
Our results on Prussian blue as well as those of Linder and Picton can be explained from the following considerations :—

Prussian blue can be hydrolysed according to the equation $Fe_4[Fe(CN)_6]_3 + 12H_2O \rightleftarrows 4Fe(OH)_3 + 3H_4Fe(CN)_6$. This hydrolysis will be checked by the presence of acids. The sol of Prussian blue will apparently be stabilised by its hydrolysis, specially due to adsorption of $Fe(CN)_6''''$ ion. Now checking of the hydrolysis of the sol due to the presence of the acids means rendering the sol unstable towards electrolytes. Consequently with small quantities of HCl or HNO_3 the sol would require smaller quantities of KCl or KNO_3 than in the absence of acids. From our experience on the phenomenon of hydrolysis of substances like aniline hydrochloride, urea nitrate etc., we know that the checking of hydrolysis by the addition of an acid or base is not directly proportional to the amounts of acid or base added; in other words, the checking of hydrolysis by the addition of a small amount of an acid or base is more marked than when larger amounts are added to check the hydrolysis. Thus it has been shown by Dhar [Zeit. Anorg. Chem. *85* 198, (1924)] that on adding 13·0358 grams of urea to 125 c.c. N/15·16 urea nitrate solution, the hydrolysis is checked to an extent of about 4·6 % per gram of urea present, whilst it is checked to an extent of only 1·33 % per gram of urea when 63·7416 grams of urea are added to the same amount of nitrate solution. Consequently when say 0·1 c.c. of HCl is added to a sol of Prussian blue, the checking of the hydrolysis of a sol will be

more marked than when 1·70 c.c. of HCl is added to the same volume of the sol, when we are considering the checking of hydrolysis by a definite amount of HCl; in other words in presence of HCl the amount of KCl smaller than the calculated quantity will be required to coagulate the sol, and this effect will be more marked when small quantities of HCl are added. Exactly similar explanation is applicable to the results obtained with HNO_3 and KNO_3 in the coagulation of Prussian blue. Moreover, there is the possibility that the activity of H° ion from HCl or HNO_3 is increased in presence of KCl or KNO_3.

The results of Linder and Picton (loc. cit) on the coagulation of As_2S_3 by a mixture of an acid and its salt can also be similarly explained. It is well known that As_2S_3 sol is hydrolysed as in the equation $As_2S_3+3H_2O \rightleftarrows As_2O_3+3H_2S$ and this hydrolysis is also checked by the presence of acids. In a foregoing paper (loc. cit) we have proved that this hydrolysis makes the sol more stable towards KCl. Consequently by the presence of acids like HCl, HNO_3 etc., smaller quantities of KCl, KNO_3 etc., would be required to coagulate the sol of As_2S_3.

In our experiments on the coagulation of Prussian blue by a mixture of KCl and $BaCl_2$ it will be seen that the amount of $BaCl_2$ necessary for complete coagulation goes on increasing with the increase in the concentration of of KCl up to a limiting value. After this limiting value is attained if the concentration of KCl is increased, the amount of $BaCl_2$ necessary for complete coagulation goes on decreasing. Exactly similar behaviour was observed by Linder and Picton (loc. cit) with As_2S_3 sol when coagulated by a mixture of KCl and $SrCl_2$ and by Weiser [Jour. Phys. Chem. *25*, 665, (1921); *28*, 232, (1924)] in the coagulation of the same sol by KCl and $BaCl_2$, LiCl and $BaCl_2$ etc.


Logs of the differences between observed and calculated amts of $BaCl_2$
Logs of the amts. of KCl added
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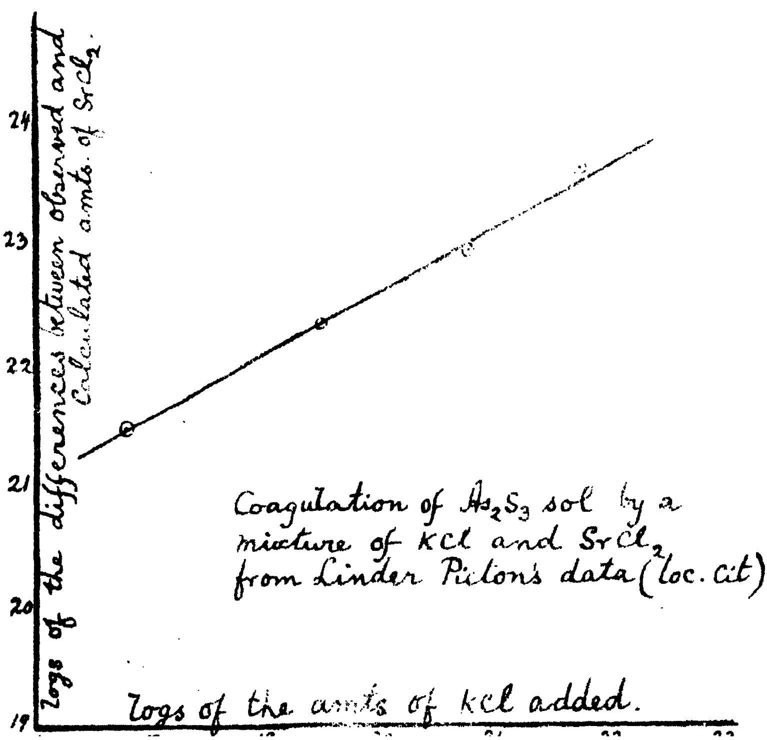

Logs of the differences between observed and calculated amts. of $SrCl_2$
Logs of the amts. of KCl added.
Coagulation of As_2S_3 sol by a mixture of KCl and $SrCl_2$ from Linder Picton's data (loc. cit)
24
23
22
21
20
19

From these results a very interesting point can be drawn out. It is well-known that keeping the amount of adsorbent constant the greater the concentration of the electrolyte which will be adsorbed the greater is the amount of adsorption. Now as the concentration of KCl, LiCl etc., is increased the amount of adsorption due to chemical attraction of Cl ions goes on increasing and consequently the sols like As_2S_3, Sb_2S_3 and Prussian blue become more and more stable and thus take more and more of $BaCl_2$, $SrCl_2$ etc., for complete coagulation. The adsorption of chlorine ions mainly from KCl by As_2S_3, Prussian blue etc., follows the general exponential formula of Freundlich. We have drawn graphs with our results as well as from the results of Linder and Picton. In these graphs the logarithms of the difference between the observed and calculated values is plotted as the amounts adsorbed (ordinates) whilst the logarithms of the concentration of KCl is plotted as abscissæ. It will be seen from the graphs that they are more or less straight lines.

In this paper we have been able to establish a very important point on the coagulation of sol by electrolytes and this will throw a flood of light on the coagulation of sols by different electrolytes. It is very interesting to observe that positively charged ferric hydroxide, which behaves normally towards dilution when coagulated by KCl, $KBrO_3$ etc. behaves abnormally towards dilution when coagulated by $FeCl_3$, $Al(NO_3)_3$ etc. Moreover ferric hydroxide is normal when coagulated by a mixture KCl and K_2SO_4 whilst it behaves abnormally when coagulated by a mixture of $Al(NO_3)_3$ and K_2SO_4. Also this sol hardly shows any acclimatization with KCl, whilst it shows markedly the phenomenon of acclimatization when coagulated by $Al(NO_3)_3$. Consequently our proposition, advanced in the previous

paper, in which it was stated, that abnormal behaviour towards dilution and towards mixed electrolytes and the phenomenon of acclimatization are connected and go hand in hand and are mainly due to the adsorption of ions carrying the same change as the sol, is highly strengthened by these researches.

The coagulation of As_2S_3 by KCl, LiCl etc., is abnormal towards dilution and we have already indicated that this sol is abnormal towards a mixture of electrolytes and markedly shows the phenomenon of acclimatization. But with $AgNO_3$ we have proved that the sol behaves normally on dilution. Consequently it seems very likely that even this sol will behave normally towards mixture of $AgNO_3$ and $Ba(NO_3)_2$ or $AgNO_3$ and $Al(NO_3)_3$. Moreover this sol will not show the phenomenon of acclimatization with $AgNO_3$, $Pb(NO_3)_2$ etc. Of course we do not ignore the possibility of the chemical reaction between these electrolytes and the sols.

In a previous paper we have obtained the following results in the coagulation of Sb_2S_3 sol by $Ba(NO_3)_2$ and $Pb(NO_3)_2$.

TABLE XXVI.

Strength of antimony sulphide sol (4A)=4 grms. pot. antimony tartrate per litre.

Electrolyte	Sol 4 A	Sol 2 A	Sol A
$Ba(NO_3)_2$ N/100	0·45c.c.	0·5c.c.	0·5c.c.
$Pb(NO_3)_2$ N/100	1·2c.c.	0·8c.c.	0·6c.c.

It will be evident from the above results that the precipitation values of $Ba(NO_3)_2$ is practically constant when Sb_2S_3 sol is diluted, whilst that of $Pb(NO_3)_2$ is practically directly proportional to the concentration of the sol, in other words more concentrated sols require greater quantities of $Pb(NO_3)_2$ than diluted ones. This difference in the behaviour of $Ba(NO_3)_2$ and $Pb(NO_3)_2$

is due to the more marked adsorption of Pb ion than that of Ba ion by Sb_2S_3 sol; in other words the ratio of the adsorption of Ba ion to that of NO_3 ion is less than that of Pb ion to NO_3 ion by Sb_2S_3. This behaviour of Pb $(NO_3)_2$ with Sb_2S_3 is more or less allied to that of $AgNO_3$ towards As_2S_3 sol as investigated in this paper. Consequently it is very likely that in the coagulation of Sb_2S_3 by a mixture of electrolytes like $Pb(NO_3)_2$ and $Al(NO_3)_3$ more or less additive relationship should be obtained and no marked acclimatization be observed with Sb_2S_3 sol and $Pb(NO_3)_2$.

In a recent paper Freundlich and Wosnessensky [Koll. Zeit. *33*, 222, (1923)] have observed the coagulation of $Fe(OH)_3$ sol obtained (*i*) by the oxidation of $Fe(CO)_5$ by H_2O_2 and (*ii*) by hydrolysis of $FeCl_3$ solution. The following results have been obtained by them.

Electrolyte.	Precipitation value with $Fe(OH)_3$ sol from Fe $(CO)_5$	Precipitation value with $Fe(OH)_3$ sol from $FeCl_3$
KCl	5·4	240
$\frac{MgCl_2}{2}$	5·6	250
$\frac{BaCl_2}{2}$	6·4	280
$\frac{AlCl_3}{3}$	>200	500
$\frac{FeCl_3}{3}$	>200	>400

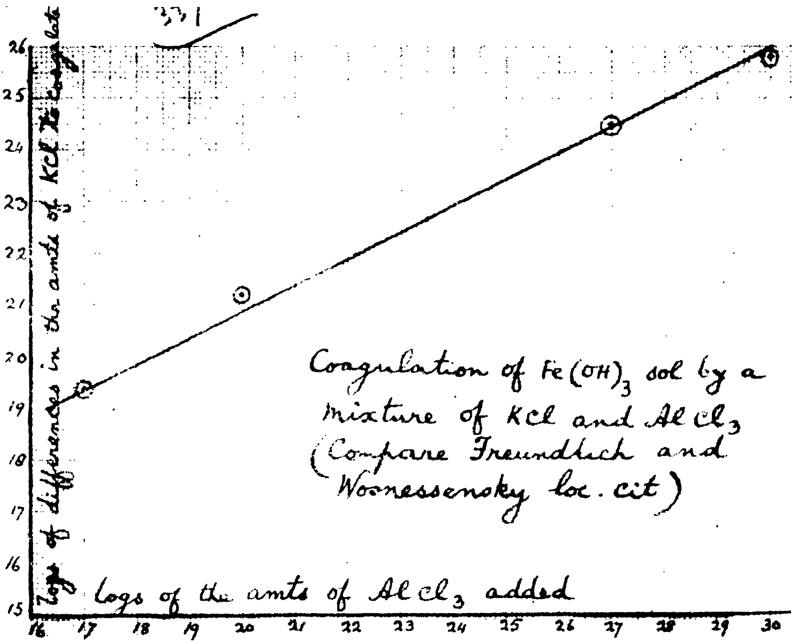
It is very evident from the above table that more of $FeCl_3$ etc., are necessary to coagulate a sol of $Fe(OH)_3$ than an equivalent amount of KCl. This is certainly due to the fact that the sol is peptised by the adsorption of Fe, Al ions etc.

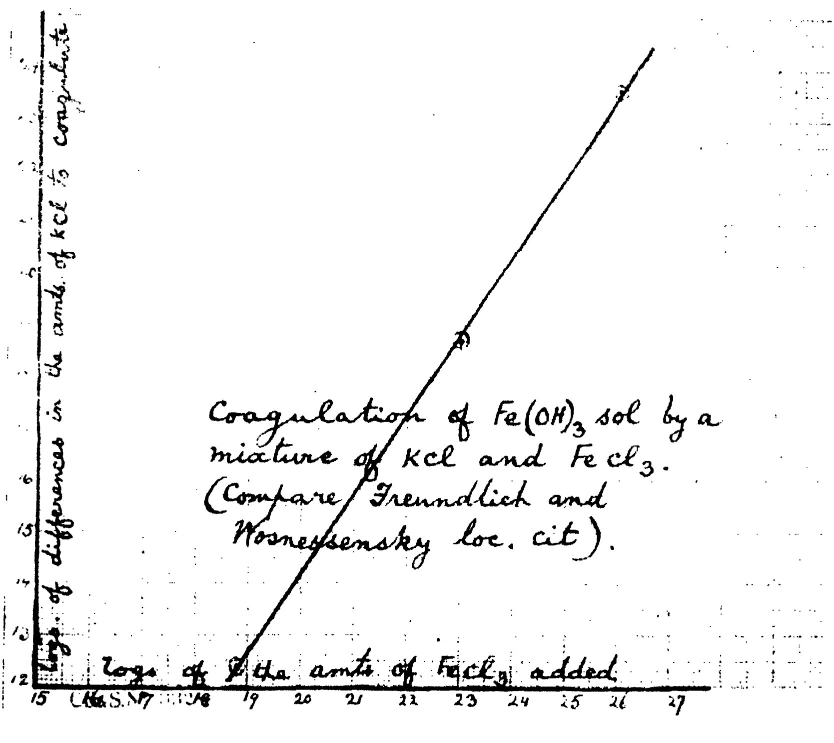
Some more interesting results have been obtained by the above authors in their investigation on the coagulation

of sol by mixtures like $FeCl_3$ and KCl, $AlCl_3$ and KCl, $La(NO_3)_3$ and KCl etc.

From their data it is evident that the sol gets stabilised by the adsorption of Fe, Al, La ions etc., and consequently more and more of KCl is necessary for complete coagulation, when the concentration of substances like $FeCl_3$, $AlCl_3$, $La(NO_3)_3$ etc., are increased. It will be evident from the following graphs that the adsorption of Al, Fe, and La ions by a sol of $Fe(OH)_3$ follow the general adsorption formula and straight lines are obtained when the logarithms of differences in the amount of KCl necessary for coagulation of the sol are plotted as ordinates, and the logarithms of the amounts of $FeCl_3$, $AlCl_3$ etc., added as abscissæ. This results obtained by Freundlich and Wosnessensky (loc. cit) corroborate our view on the subject and we are strongly of the opinion that sol like As_2S_3, Sb_2S_3, mastic etc., are stabilised by the adsorption of the negatively charged ions and show abnormal behaviour on dilution when coagulated by KCl, LiCl etc., and are abnormal towards a mixture of electrolytes, and show the phenomenon of acclimatization markedly. Similarly sols like $Fe(OH)_3$, $Cr(OH)_3$ etc., behave normally towards dilution, towards mixture of electrolytes and do not show the phenomenon of acclimatization when coagulated by KCl, $KBrO_3$, K_2SO_4 etc.,; on the other hand these very sols show abnormal behaviour on dilution when coagulated by $FeCl_3$, $CrCl_3$, $Al(NO_3)_3$ etc., and behave abnormally towards mixtures of electrolytes like $FeCl_3$ and K_2SO_4, $CrCl_3$ and K_2SO_4 etc., and show the phenomenon of acclimatization markedly when coagulated by $FeCl_3$, $Al(NO_3)_3$ etc. This is due to the stabilisation of the sol by the adsorption of ions carrying the same charge as the sol, and this adsorption follows the ordinary exponential formula of Freundlich.

Opposite to p. 360





The coagulations of As_2S_3 and of $Fe(OH)_3$ have been effected by $BaSO_4$ at various dilution of the sols and it will be seen in both these cases, that the greater the concentration of the sol, the greater would be the amount of $BaSO_4$ necessary for coagulation. This is because the question of adsorption of ions carrying the same charge as the sol does not enter in the coagulation of sols by freshly precipitated $BaSO_4$. Similarly we have proved experimentally that in the coagulation of As_2S_3 sol by positively charged $Fe(OH)_3$ sol the greater the concentration of As_2S_3, the greater is the amount of $Fe(OH)_3$ necessary for coagulation.

In a previous paper [Ghosh and Dhar, Koll. Zeit, (1924)] we have shown that when KCl is used as the coagulating agent diluted sols of As_2S_3 and Sb_2S_3 do not coagulate even after the lapse of 16 hours when sufficient electrolytes are added to coagulate the concentrated sols in an hour. In the same paper we came to the conclusion that the view advanced by Kruyt and Spek [Zeit. Koll. *25*, 3, (1919)] and Mukerji and Sen [Jour. Chem. Sec. *115*, 461, (1919)] that the decreased chance of collision amongst the colloidal particles is an important factor that prevents a weaker sol of arsenious sulphide from coagulating is not corroborated by experiment.

From the results obtained in this paper on the coagulation of sols by freshly precipitated $BaSO_4$, where the coagulation is more or less of a mechanical nature, and is caused by the collision of colloid particles with the particles of barium sulphate, we observed that the amount of $BaSO_4$ necessary for complete clearing (coagulation) of a sol decreases with the decreasing concentration of the sol. Similarly from our experiments on the coagulation of As_2S_3 sol by $Fe(OH)_3$ sol we find that less the concentration of As_2S_3, the less is the amount of $Fe(OH)_2$ necessary for coagulation.

According to Kruyt and Spek and Mukerji and Sen dilution of a sol of As_2S_3 leads to its stabilisation due

to the decreased chance of collision amongst the colloidal particles towards precipitants; if such is the case, then more of precipitants like freshly precipitated $BaSO_4$, positively charged $Fe(OH)_3$ etc., would be necessary to coagulate a dilute sol of As_2S_3 than a concentrated one, but as a matter of fact experimental results show that the greater the concentration of As_2S_3 sol the greater is the amount of $BaSO_4$ or $Fe(OH)_3$ sol necessary for coagulation. Consequently the dilution rule based on the phenomenon of adsorption that the greater the concentration of a sol the greater is the amount of precipitant necessary for coagulation has a general application. Our results on the coagulation of Sb_2S_3 sol in presence of KOH show that in general as the concentration of KOH is increased greater quantities of univalent, bivalent, and trivalent electrolytes are necessary to coagulate the sol.

It has been observed in a previous paper (Koll. Zeit. 1924) that OH ions even in traces exert great peptising effect on Sb_2S_3, As_2S_3, SnS_2 etc. Thus 5 c.c. NaOH N/100 solution is sufficient to convert 1 gram of As_2S_3 in colloidal condition. Similar results were obtained with Sb_2S_3, SnS_2 etc. It is well-known that OH' ions have a great chemical affinity for these sulphides and exert solvent action on them, and hence the sols become stable towards all electrolytes when KOH is added to the sulphide sol.

From our experiments on the coagulation of As_2S_3 and Sb_2S_3 by electrolytes in presence of non-electrolytes like ethyl alcohol, propyl alcohol, urea and cane sugar, we observe that both the sols become more stable towards all electrolytes in presence of ethyl and propyl alcohols. The stabilising influence of these alcohols on As_2S_3 and Sb_2S_3 sols is more pronounced when the above sols are coagulated by bi and trivalent ions than

when the sols are coagulated with monovalent electrolytes. With urea and cane sugar both the above sols become unstable towards all electroytes.

In this connection it will be interesting to discuss the works of other investigators on the influence of non-electrolytes on the coagulation of sols. Kruyt and Duin [Koll. Chem. Beihefte *5*, 269 (1914)] have shown that As_2S_3 becomes unstable towards uni and trivalent cations and becomes stable towards bi- and quadri-valent cations in presence of non-electrolytes like ethyl, propyl and iso-amyl alcohols Whilst with $Fe(OH)_3$, they have observed that the sol becomes unstable when coagulated by KCl. K_2SO_4 etc., in presence of phenol and iso-amyl alcohol, Gold sol is stabilised by other and iso-amyl alcohol. On the other hand, Freundlich and Rona [Biochem. Zeit. *181*, 87, (1917)] have shown that $Fe(OH)_3$ becomes unstable towards KCl, KBr etc., but not with K_2SO_4 and potassium citrate in presence of urethanes, camphor, amyl-alcohol, thymol etc. They have also shown that such substances like thymol, camphor etc., diminish the rate of movement of $Fe(OH)_3$ sol in an electric field, and they explain this behaviour on the view of adsorption of the substances on the surface of the colloid particles and the diminution in dielectric constant.

Rona and Gyorg (Biochem. Zeitech *105*, 133, 1920) have shown that a suspension of kaolin becomes unstable towards electrolytes in presence of several alcohols, chloroform, camphor, thymol etc.

From the above results it is difficult to draw any definite conclusion with regard to the coagulation of sols by electrolytes in presence of non-electrolytes. We have observed that the presence of alcohols makes the sols of Sb_2S_3 and As_2S_3 stable towards electrolytes especially bi- and trivalent cations, whilst Kruyt and Duin (loc. cit) have observed the stabilising influence of non-electrolytes

towards the coagulation of As_2S_3 by bi- and tetravalent ions. With gold they have shown the sol becomes stable towards uni and tri-valent ions and unstable towards bi-valent cations in presence of ether and amyl alcohol.

It will be interesting to observe that we have shown that in presence of H_2S both Sb_2S_3 and As_2S_3 sols become stable towards uni and tri-valent cations and unstable towards bi-valent cations. It is apparent therefore, that the results on the influence of non-electrolytes on the coagulation of sol are rather discordant and insufficient for a satisfactory explanation to be advanced.

Summary.

1. In this paper further evidence has been brought forward in favour of the view that (1) abnormal behaviour on dilution; (2) abnormality towards a mixture of eletrolytes and (3) the phenomenon of acclimatization are essentially connected and go hand in hand. A dilute sol of Prussian blue takes up more KCl than a concentrated one for coagulation. This sol does not show additive relationship when coagulated by a mixture of electrolytes of varying valency and it also shows the phenomenon of acclimatization markedly. In these respects this sol behaves exactly like arsenious sulphide sol.

2. Smaller quantities of KCl or KNO_3 are required when Prussian blue is coagulated in presence of HCl or HNO_3. An explanation based on the phenomenon of hydrolysis has been advanced.

3. When to $Fe(OH)_3$ sol (positive) is coagulated by $Al(NO_3)_3$ $FeCl_3$ etc., the dilute sol takes up more electrolyte than the concentrated one. Moreover this sol behaves abnormally when coagulated by a mixture of electrolytes like $Al(NO_3)_3$ and K_2SO_4, $FeCl_3$ and K_2SO_4 etc. $Fe(OH)_3$ sol shows the phenomenon of acclimatization markedly when coagulated by $Al(NO_3)$, $FeCl_3$, etc.

On the other hand, this sol is normal towards dilution when coagulated by KCl, $KBrO_3$ etc., and is also normal towards a mixture of electrolytes like $KBrO_3$ and $K_4C_2O_4$, KCl and K_2SO_4 etc., and does not show the phenomenon of

acclimatization appreciably when coagulated by $KBrO_3$, $K_2C_2O_4$ etc.

An explanation of these results based on the phenomenon of the adsorption of ions carrying the same charge as the sol has been advanced.

4. When As_2S_3 sol is coagulated by $AgNO_3$, the concentrated sol requires more of $AgNO_3$ than a dilute sol for complete coagulation and, therefore, behaves normally on dilution towards $AgNO_3$. As_2S_3 sol behaves abnormally on dilution when coagulated by univalent salts like KCl, NaCl etc., and the normal behaviour towards $AgNO_3$ is explained from the view that Ag ions are highly adsorbed by As_2S_3. It has been suggested that certain monovalent organic cations, which are known to be highly adsorbed will also show similar normal behaviour with As_2S_3 sol.

5. The influence of several non-electrolytes on the coagulation of As_2S_3 and Sb_2S_3 sols has been investigated. It is not yet possible to put forward a satisfactory explanation of the influence of non-electrolytes on the coagulation of sols.

ON THE STABILITY OF COLLOIDAL SOLUTIONS.

Part II.—The stability of colloidal chromium hydroxide and copper ferrocyanide solutions in presence of stabilising ions, and the coagulation of colloids by mixture of electrolytes.

KSHITISH CHANDRA SEN AND MOOLRAJ MEHROTRA.

Chemistry Department, Allahabad University.

In the first part of this series of papers,[1] it has been shown that the presence of stabilising electrolytes in the case of some sols have a marked effect on the coagulation of these colloids by other precipitating ions. Thus in the case of colloidal ferric hydroxide prepared by boiling a ferric chloride solution, the addition of free hydrochloric acid stabilises the sol considerably so far as coagulation by potassium sulphate is concerned. The more dialysed and hence the more pure the sol becomes, its stability also becomes less, and an undialysed sol requires greater amounts of electrolytes for coagulation than a dialysed sol. The following experimental results are taken from the previous paper. The concentration of the colloid was equal in both the cases.

lectrolyte	Dialysed sol	Undialysed sol
2N KNO_3	3·0 c. cm.	6·1 c. cm.
2N $BaCl_2$	3·2 c. cm.	7·2 c. cm.
N/100 $MgSO_4$	0·8 c. cm.	1·6 c. cm.
N/200 $CdSO_4$	0·6 c. cm.	1·8 c. cm.

[1] K. C. Sen, Jour. Phys. Chem. *28*, 1029, (1924).

From these results it appeared that the presence of some free hydrochloric acid considerably stabilises a sol of ferric hydroxide.

A few years ago Neidle[1] showed that the stability of colloidal ferric hydroxide depends not so much on the method of preparation of the sol, but mainly on the amount of impurity contained in the sol. By adding successive quantities of hydrochloric acid to an well dialysed sol of ferric hydroxide, and coagulating a fixed volume of it with potassium sulphate, he showed that the quantity of electrolyte K_2SO_4 necessary for coagulation at first increases with the concentration of the added HCl, then comes to a maximum and then actually decreases. This shows that the gradual addition of acid cannot stabilise a colloid to an infinite extent. In the previous paper we have also studied the effect of gradual addition of acetic acid, propionic and benzoic acids to a suspension of aluminium hydroxide stabilised by these acids respectively. By starting with a freshly precipitated and well-washed aluminium hydroxide stabilised into a positively charged suspension by means of benzoic acid, it has been shown that the stability of these suspensions so far as coagulation by K_2SO_4 is concerned, reaches a maximum with the increase in the addition of the acids and then decreases. This fact has been explained by the view that the first stabilisation is due mainly to the adsorption of H° ions from the acid, but gradually with the increase in the concentration of the acid, the concentration of the negative ion in the solution increases and exerts a coagulating effect. Also the adsorption of H° ion by the particles of the suspension has been found to reach a maximum, and hence owing to the balancing of these factors, a maximum in stability soon occurs. These studies are interesting

[1] M. Neidle. Jour. Amer. Chem. Soc. *39*, 2334, (1917).

because they throw considerable light upon the stability relations of a colloid, and it was thought desirable to have more experimental results of this nature. In this paper an account of some experiments have been given. The first experiment was done with chromium hydroxide sol.

EXPERIMENTAL PART.

Colloidal chromium hydroxide was prepared by peptising chromium hydroxide by means of chromium chloride solution. The colloid was dialysed in the cold for about six weeks when no trace of chloride could be obtained in the external water of the parchment dialyser. The colloid was not acidic, but on dissolving in nitric acid, it still gave a slight precipitate with silver nitrate. This much of chloride could not be removed from the sol by dialysis. The concentration of the sol was 1·86 gr. per litre. The method of finding out the coagulation point was as follows:—5 c.c. of the sol was taken in a clean test tube, and in another test tube, a known amount of HCl mixed with a known amount of the electrolytes whose coagulating power was being measured, was made up to 5 c. cm. with water. These two liquids were then rapidly mixed together for several times, and then set aside for coagulation to take place. The total volume of the mixture was always 10 c. cm. and the usual methods of having perfectly clean test tubes were adopted. In the case of KCl, the time allowed was one hour, but in the case of K_2SO_4 and $K_2C_2O_4$, the point of immediate coagulation was observed. This was due to the fact, that with KCl a little uncertainty to obtain the exact coagulation point, was experienced. In coagulation experiments, usually an arbitrary time limit is set up as standard, and in a series of experiments, only the relative values can be obtained. In the following tables, the results of the precipitation values are given. The results were in every case reproducible.

TABLE II

Electrolytes :—$HCl + K_2SO_4$

Amount of HCl N/100 taken in c. cm.	Amount of K_2SO_4 N/100 required for coagulation in c. cm.
0·0	2·4
0·1	2·9
0·2	3·0
0·3	3·3
0·4	3·5
0·5	3·7

TABLE III

Electrolytes :—$HCl + K_2C_2O_4$

Amount of HCl taken in c. cm.	Amount of $K_2C_2O_4$ N/100 added to coagulate in c. cm.
0·0	3·0
0·1	3·2
0·2	3·3
0·3	3·32
0·4	3·34
0·5	3·34

TABLE IV

Electrolytes :—$HCl + KCl$

amount of HCl $\frac{N}{100}$ taken in c. cm.	Amount of KCl 2N added to coagulate sol in c. cm.
0·0	2·5
·1	3·25
2	3·5

So far only the effect of acid on the stability of the colloid has been examined. It will be observed that in all the three cases, the colloid becomes considerably stable with the gradual addition of the acid, but with K_2SO_4 and $K_2C_2O_4$, the stability gradually reaches a maximum. In the following table the effect of the mixtures of the electrolytes K_2SO_4 and $K_2C_2O_4$ has been examined to see whether any one of these electrolytes exert any appreciable stabilising action on the chromium hydroxide sol.

TABLE V

Electrolytes :—$K_2SO_4 + K_2C_2O_4$

amount of K_2SO_4 $\frac{N}{100}$ taken in c. cm.	Amount of $K_2C_2O_4$ $\frac{N}{100}$ required to complete precipitation		Difference.
	Observed.	Calculated.	
0	3·0		
0·2	2·8	2·75	0·05
0·4	2·55	2·5	0·05
0·6	2·25	2·25	0
0·8	2·0	2·0	0
1·0	1·8	1·75	0·05
2·4	0		

The amount of K_2SO_4 N/100 required to coagulate the sol is 2·4 c. cm. The theoretical coagulation values given in the above table has been calculated on the assumption that 2·4 c. cm. of K_2SO_4 N/100 is equivalent to 3·0 c. cm. of $K_2C_2O_4$ N/100. It will be observed that the difference between the calculated and the observed

values is within the experimental error and hence we can take the coagulative powers of these two salts as additive. This fact has already been noticed by Weiser[1] who also finds that a mixture of $KCl+K_2SO_4$ also gives approximately additive relations. Neither of these electrolytes therefore stabilises colloidal chromium hydroxide, and this case is different from that studied with acids.

Experiments with copper Ferrocyanide sol.

The coagulation of copper ferrocyanide has been studied by Pappada[2] and he has shown that the Schulze-Hardy law is applicable to this colloid. He, however, did not study the stability relations of this colloid in detail. It is well-known that colloidal copper ferrocyanide is negatively charged owing to the adsorption of ferrocyanide ions, and it is not possible to free either Prussian blue or copper ferrocyanide from adsorbed potassium ferrocyanide. In our present investigation, about 3% solution of copper chloride was mixed with a little excess of potassium ferrocyanide and the precipitate of copper ferrocyanide was filtered off. On washing with distilled water several times, the excess of potassium ferrocyanide was removed and the precipitate began to pass through the filter paper as a colloid. The first hundred c.c. was rejected and then about a litre of the pure colloid was collected by continual washing with distilled water. This colloidal solution was then dialysed in a parchment dialyser for a month with frequent changes of the external water. The resulting sol was very stable, but owing to the method of preparation, somewhat dilute. Sufficient quantity of the sol was prepared to complete the whole series of experiments. The concentration of the sol was 1·3 grms. per litre. The method of determining the coagulation values of the

[1] Weiser, Jour. Phys. Chem. *28*, 232, (1924).

[2] N. Pappada, Kolloid Zeit. *9*, 136 (1911).

electrolytes was the same as in the case of chromium hydroxide, and in every case the coagulation point was determined one hour after mixing the electrolyte with the sol. In the following tables the effect of addition of potassium ferrocyanide on the stability of the copper ferrocyanide sol is shown.

TABLE VI.

Electrolytes $K_4Fe(CN)_6 + KCl$.

Amount of $K_4Fe(CN)_6$ N/2 taken in c. cm.	Amount of KCl N/4 required for coagulation.		Difference.
	Observed.	Calculated.	
0·0	1·6	—	
0·1	2·05	1·54	0·51
0·5	2·0	1·31	0·69
1·0	1·75	1·03	0·72
1·5	1·4	0·745	0·655
2·0	0·95	0·46	0·49
2·8	0·0	—	—

TABLE VII.

Electrolytes $K_4Fe(CN)_6 + BaCl_2$

Amount of $K_4Fe(CN)_6$ N/2 taken.	Amount of $BaCl_2$ N/500 for coagulation.		Difference.
	Observed.	Calculated.	
0·0	1·9		
0·3	2·2	1·69	0·51
0·5	2·5	1·56	0·94
0·8	2·8	1·36	1·44
2·0	3·0	0·24	1·80
2·2	2·7	0·41	2·2
2·8	0·0		

Potassium ferrocyanide itself coagulates the sol at a concentration of 2·8 c. cm. These results therefore show that with the gradual addition of the potassium ferrocyanide, the stability at first increases and then reaching a maximum, decreases. In the following tables, the results with potassium chloride, hydrochloric acid and caustic potash are given.

TABLE VIII.

Electrolytes $KCl+BaCl_2$

Amount of KCl N/4 taken.	Amount of $BaCl_2$ N/500 for coagulation.		Difference.
	Observed.	Calculated.	
0·0	1·9		
0·1	1·1	1·78	—0·68
0·2	0·65	1·66	—1·01
0·3	0·5	1·54	—1·04
0·4	0·4	1·42	—1·02
0·5	0·35	1·30	—0·95

TABLE IX.

Electrolytes $HCl+BaCl_2$.

Amount of HCl $\frac{N}{100}$ taken in c. cm.	$BaCl_2$ $\frac{N}{500}$ required for coagulation.
0·0	1·9
0·2	1·8
0·4	1·7
0·6	1·45
0·8	1·40
1·0	1·35

TABLE X.

Electrolytes $KOH+BaCl_2$

Amount of KOH $\frac{N}{100}$ taken in c. cm.	Amount of $BaCl_2$ N/500 required for coagulation.
0·0	1·9
0·2	2·05
0·4	2·1
0·6	2·05
0·8	1·9
1·0	1·85

It will appear from these results that the addition of KCl does not stabilise the colloid towards $BaCl_2$. On the other hand far less quantities of $BaCl_2$ are required to complete the coagulation of the sol in presence of KCl than in its absence. Several experiments were tried with $Al_2(SO_4)_3$ as the precipitating electrolyte in presence of KCl, and similar results were obtained. The addition of HCl also does not stabilise the colloid, and its behaviour is exactly analogous to that of KCl. Caustic potash stabilises the sol to a certain extent, but the stability soon reaches a maximum and then decreases. The stabilisation is undoubtedly due to the presence of OH' ions which stabilises the negatively charged suspension of copper ferrocyanide.

THEORETICAL PART.

Within the last few years, a number of investigations have been published dealing with the stability of colloidal solutions. The effect of concentration of the colloid on

its coagulation by electrolytes,[1] the charge reversal of colloids by means of suitable ions,[2] the peptisation of metallic hydroxides and salts in presence of non-electrolytes and amphoteric electrolytes[3] and the effect of the ion having the same charge as the colloidal particles themselves possess,[4]—all of these facts have been studied more or less, and some interesting observations have been made. It has been found, for example, that usually dilution of a sol makes it less stable towards electrolytes irrespective of the valency of the precipitating ion. This is true of colloidal ferric hydroxide, aluminium hydroxide, chromium hydroxide, stannic hydroxide, Prussian blue etc. Several exceptions have also been noticed, namely, in the case of arsenious sulphide and antimony sulphide sols, dilution generally makes the sol more stable towards some univalent precipitating ions. In a previous paper[5] an explanation of this exceptional behaviour was offered by assuming that the anomaly is mainly due to the effect of the ion charged oppositely to that of the precipitating

[1] E. Burton and Bishop, Jour. Phys. Chem. *24*, 701, (1920). E. Burton and E. D. MacInnes, *Ibid* *25*, 517, (1921). J. Mukherjee. J. Amer. Chem. Soc. *37*, 2024. (1915) : J. Mukherjee and N. Sen, J. Chem. Soc. *115*, 462. (1919) : *117*, 350, (1920.) H. Weiser and H. O. Nicholas, Jour. Phys. Chem. *25*, 742. (1921). K. C. Sen, P. B. Ganguly and N. R. Dhar, *Ibid*, *28*, 313, (1924). K. C. Sen. and N. R. Dhar. Kolloid Zeit, *34*, 262, (1924).

[2] N. R. Dhar and K. C. Sen, Jour. Phys. Chem *27*, 376, (1923). N. R. Dhar, K. C. Sen and S. Ghosh, *Ibid* *28*, 457, (1924) ; J. Mukherjee and B. C. Roy. Jour. Chem. Soc. *125*, 476, (1924).

[3] K. C. Sen and N. R. Dhar, Kolloid Zeit. 27, *33*, 193, (1923).

[4] K. C. Sen and N. R. Dhar, *Ibid*. *34*, 262, (1924). J. Mukherjee and S. G. Choudhuri, Jour. Chem. Soc. *125*. 794 (1924).

[5] Kolloid Zeit. *34*, 262 (1924)

ion. The ion carrying the same charge as the sol tends to peptise the sol and makes it more stable. This effect will be more marked in the case of univalent salts where the precipitation value is usually very high, and consequently the concentration of the ion charged oppositely to the precipitating ion is great. In the case of salts containing bivalent or trivalent precipitating ions, this effect will be less prominent as the precipitation value is less and frequently the stabilising ion has a valency less than that of the precipitating ion. Support to this view was also obtained from the experimental results on the influence of ions carrying the same charge as that on the sol on its coagulation by electrolytes. From the experimental results cited in the previous paper, it was observed that greater the valency of the negative ion, the greater is the stabilising effect on a negatively charged sol of arsenious sulphide. The precipitation values of different potassium salts according to Schulze, are in the order, $Fe(CN)_6'''' > SO_4'' > C_2O_4'' >$ tartrate$'' > NO_3' > I' > Cl' > ClO_3' > Br'$, beginning with the greatest precipitation value. If however a bivalent ion be chosen as the coagulating ion, the precipitation values do not differ much. It has already been shown that in the case of monovalent potassium, the difference in the precipitation values of the foregoing salts comes to about 20 per cent. from the average, whereas if calcium be taken as the precipitating ion, the difference comes out to be about one per cent. from the average. With trivalent aluminium as the coagulating ion, the difference in the precipitation values of the sulphate, nitrate, and the chloride is only slight. The effect of dilution of chromium hydroxide sol on its coagulation by electrolytes has already been examined by H. Weiser and H. O. Nicholas (loc cit). In the following table the effect of dilution of copper ferrocyanide sol on its stability in presence of electrolytes is given.

TABLE XI.

Electrolyte.	KCl N/4.	$K_4Fe(CN)_6$ N/2.	$BaCl_2$ N/500.	$Al_2(SO_4)_3$ N/800.
Original sol ...	1·6 c.c.	2·8	1·9	1·35
4/5 diluted sol ...	2·0			0·95
1/2 diluted sol ...	2·2	3·1	2·1	0·85
1/4 diluted sol ...		4·2	2·45	

From the above table it will be observed that more KCl and $K_4Fe(CN)_6$ are required for the dilute sol than for the concentrated sol. This result seems peculiar for H. Weiser and H. O. Nicholas (loc. cit) have shown that colloidal Prussian blue follows the general rule that greater the concentration of the sol greater the quantity of electrolyte necessary for its coagulation. The case of colloidal copper ferrocyanide seems therefore to be analogous to that of arsenious and antimony sulphide sols. The case of barium chloride where also more of the electrolyte is necessary for the coagulation of the diluted sol seems anomalous, though it is by no means unique. Several cases are known in the literature where bivalent precipitating ions require more of the salt to coagulate a diluted sol than the original sol. Thus in a previous paper,[1] we have found the following results.

TABLE XII.

Sol.	Electrolyte.	Original sol.	1/2 diluted.	1/4 diluted.
$Fe(OH)_3$	$MgSO_4$ N/200	0·65 c.c.	0·6	0·8
Sb_2S_3	$Ba(NO_3)_2$ N/100	0·45	0·5	0·5

[1] K. C. Sen, P. B. Ganguly and N. R. Dhar, (loc cit).

Similar results have also been found by E. Burton and Bishop (loc. cit) with arsenic sulphide sol and magnesium chloride, where the amounts of the electrolyte required to coagulate the same volume of the sol of concentration one and 1/8th of the original were respectively 9·3 and 9·8 c. cm. A similar thing has also been found by H. D. Murray[1] with mastic sol, whose results will be given later on. These cases are, however, not general and form exceptions to the rule already stated, that the greater the concentration of the sol the greater is the amount of electrolyte necessary for its coagulation, irrespective of the valency of the precipitating ion.

In recent years the coagulation of colloids by mixed electrolytes has received much attention. The importance of these studies immediately reveals itself when we consider that colloids are usually stabilised by the preferential adsorption of one ion, and hence in all coagulation experiments, where an electrolyte is added to a sol, the effect which is observed is really the joint effect of the adsorbed ion, and the ions of the added electrolyte. Coagulation experiments with mixtures of electrolytes therefore give us a clue as to the source of stability of the colloid, as well as, the effect of individual ions in presence of others. The experiments which have already been given are really a study of the coagulative powers of mixture of electrolytes, and hence these results will be discussed from the point of view of mixed electrolytes.

The first experiment with mixtures of electrolytes on an inorganic colloid seems to be that of Linder and Picton[2] who showed that with colloidal arsenious sulphide and a mixture of KCl and $SrCl_2$, the precipitation value of the mixed electrolytes was not the algebraic sum

[1] H. D. Murray, Phil. Mag. p, 401, August, (1922.)

[2] Linder and Picton, Jour. Chem. Sec. 67, 67, (1895.)

of the precipitation values of each separately, but considerably greater quantity of strontium chloride was necessary when KCl was already present in the arsenious sulphide sol. With increase in the addition of KCl, the amount of $SrCl_2$ gradually reached a maximum, and then became less.

The following table gives the results obtained by Linder and Picton.

TABLE XIII.

c. cm. of KCl.	c.c. of $SrCl_2$ to complete coagulation.		Difference.
	Determined.	Calculated.	
0·0	4·4		
0·3	4·9	4·2	0·7
0·6	5·4	4·0	1·4
0·9	5·5	3·8	1·7
1·2	5·55	3·6	1·95
1·5	5·7	3·4	2·3
1·8	5·9	3·2	2·7
2·1	6·0	3·0	3·0
2·4	5·7	2·8	2·9
2·7	5·65	2·6	3·05
3·0	5·3	2·4	2·9
3·3	5·1	2·2	2·9
6·6	0·0		

It will be observed that these results are exactly similar to that given in table VII with potassium ferrocyanide and barium chloride on copper ferrocyanide sol. Linder and Picton also made some experiments with mixtures of salts containing bivalent precipitating ions and showed that in this case no stabilisation of the sol occurs and the precipitation values are approximately the sum of that of each electrolyte. H. Weiser[1] studied the precipitation values of several mixtures of electrolytes such as $KCl+K_2C_2O_4$ and $K_2SO_4+K_2C_2O_4$ on a sol of positively charged ferric hydroxide and pairs of

[1] H. Weiser, Jour. Phys. Chem. *25*, 665, (1921).

such salts as $KCl+SrCl_2$ and $BaCl_2+SrCl_2$ on a negatively charged sol of arsenious sulphide. His results show that with As_2S_3 sol, the results of Linder and Picton are quite correct, that is, more of $SrCl_2$ is necessary to coagulate a fixed amount of As_2S_3 sol in presence of KCl than when it is absent. On making adsorption experiments, it was found that the presence of potassium ion markedly decreased the adsorption of Ba^{oo} ion, and Weiser explained the stability of As_2S_3 sols in presence of KCl as due to the cutting down of the adsorption of the coagulating Ba^{oo} ions. With the mixture $SrCl_2+BaCl_2$, where both the precipitating ions are bivalent, the precipitation values showed an additive relation and in this also Linder and Picton's result was corroborated. In the case of ferric hydroxide colloid, no stabilisation was observed in any case and along with it, the presence of KCl did not affect the amount of adsorption of oxalate ion. A year later H. Freundlich and P. Scholz[1] published an investigation in which they studied the effect of mixture of electrolytes on Odén's sulphur sol, von Weimarn's[2] sulphur sol, Donau's[3] gold sol and an arsenious sulphide sol. The authors confirmed the results of Odén, to the effect that the coagulating properties of a salt are diminished or destroyed by the presence of a second salt, but in contradistinction to Odén, they also found that the reduction is not due to the diminution of cation action by the anion but rather to an antagonism between the cations. The antagonistic action was measured by mixing Odén's sulphur sol with a quantity of an electrolyte insufficient to cause flocculation and then determining the quantity of a second electrolyte necessary to effect this change. The

[1]H. Freundlich and P. Scholz, Kolloid Chem. Beihefte, *16*, 267, (1922).
[2]P. Weimarn, Kolloid, Zeit. *8*, 214, (1911).
[3]Donau, Monatsh, *26*, 525, (1905).

ion pairs magnesium+lithium and magnesium+hydrogen showed strong antagonistic effect. The anions had also an influence in the diminution of the coagulation value in the order citrate > sulphate > chloride. Definitely hydrophobic sols, such as Weimarn's sulphur sol and Donau's gold sol, did not exhibit the antagonistic phenomenon. In these cases the coagulation values of sols containing electrolytes were always less than those of the pure sols; that is the action of the two electrolytes was additive. Freundlich and Scholz believed that the behaviour of Odén's sulphur sol was probably to be connected with its distinct hydrophilic character; that is with the hydration of the micellæ. In the case of arsenic sulphide sol, a certain antagonism was observed for salts such as lithium chloride and magnesium chloride, and hence this sol has also been considered by these authors to be hydrophilic.

In a recent paper H. Weiser[1] has again studied the precipitation of hydrous chromium oxide, stannic oxide and arsenious sulphide sol by various mixtures of electrolytes, and has come to the conclusion that the explanation of Freundlich and Scholz is untenable. Several well-known hydrophilic sols such as hydrous ferric oxide, chromium oxide, stannic oxide etc., show no antagonistic effect when they are coagulated by pairs of different electrolytes. On the other hand a strong antagonistic action is observed when As_2S_3 sol is coagulated by such pairs as $HCl+MgCl_2$, $LiCl+BaCl_2$ and $LiCl+MgCl_2$. Weiser therefore considers that hydration of a sol is not an important factor in producing such phenomena, and it is more possible that the antagonistic action is due to the effect of one cation upon the adsorption of the other by the colloid particles. This view is supported by the fact that the adsorption of $Ba^{\circ\circ}$ ion by As_2S_3 sol is

[1]Weiser, Jour. Phys. Chem. *28*, 232 (1924).

decreased to a marked extent by the presence of Li° ion below the precipitation concentration of the chlorides of the metals. The adsorption of Li° ion is also influenced by the presence of $Ba^{\circ\circ}$ ion. This cationic antagonism according to Weiser, is the important factor in raising the precipitation concentration of certain mixtures above the additive values.

The importance of this subject of coagulation of colloids by mixture of electrolytes has also been perceived in some biological studies, and H. Freundlich and P. Scholz have cited the works of Neuschloss on lecithin sol, J. Loeb and S. Lillie. Specially interesting in this connection is the coagulation of egg white by mixture of salts. Continuing the investigation of Schäfer, Wo. Pauli[1] observed the effect of mixtures of two salts and found that the coagulating action of salts upon proteins is additive, that is, the precipitating power of the mixture is the algebraic sum of the separate effects exerted by its components except when the two salts have a common ion and so diminish each other's degree of dissociation. Later on he found that a number of salts which will not coagulate egg-white by themselves will do so or will increase the coagulating power of other salts when mixed with them, while others markedly diminish the coagulating power of salts which in their absence, readily coagulate egg albumin. These experiments are therefore in line with those already given in the present paper.

About ten years ago, R. Bender[2] published an interesting paper which has not however received much attention, on the coagulation of mastic sol by mixture of two salts. In most cases he used HCl as one of the electrolytes and his results show that, in general, the

[1] Wo. Pauli. Bietr. Z. Chem. Physiol und Pathol *3*, 225 (1903).

[2] R. Bender, Kolloid. Zeit, *14*, 255 (1914).

substitution of an equimolar quantity of a metallic ion causes no appreciable change in the coagulating power of the acid. This relationship holds only in the case of mono and bivalent metals. In the case of tervalent metal ions a slight stabilisation of the sol is observed. In the following table the effect of HCl on the stability of the mastic sol in presence of the coagulating agent $Al_2(SO_4)_3$ is given.

TABLE XIV.

HCl added mol $\times 10^{-4}$	$Al_2(SO_4)_3$ mol $\times 10^{-4}$ required to coagulate.
0·0	0·184
0·34	0·184
0·91	0·455
1·80	0·455
2·80	0·455
3·60	0·276
6·30	0·0

It will be observed that a mixture of $Al_2(SO_4)_3 + HCl$ does not show any additive relation with regard to their precipitation values on mastic sol. This behaviour is not, however, noticed when NaCl is substituted for HCl. Also pairs of electrolytes like $MgSO_4 + HCl$, $BaCl_2 + HCl$, $LiCl + HCl$, $Ce(NO_3)_3 + HCl$, $CdSO_4 + HCl$ do not show any antagonistic effect but a mixture of $AuCl_3 + HCl$, and $HgCl_2 + HCl$ show this behaviour. Since colloidal mastic is usually negatively charged, it was expected that in presence of OH' ions the stability would be increased. This was found to be true by R. Bender who observed that in presence of NaOH and $Ba(OH)_2$ more of NaCl was required to coagulate the colloid. A similar effect was observed in the case of the pair of electrolytes KCN + NaCl where the stabilisation is undoubtedly due to the OH ions set free by the hydrolysis of

Opposite to p. 385

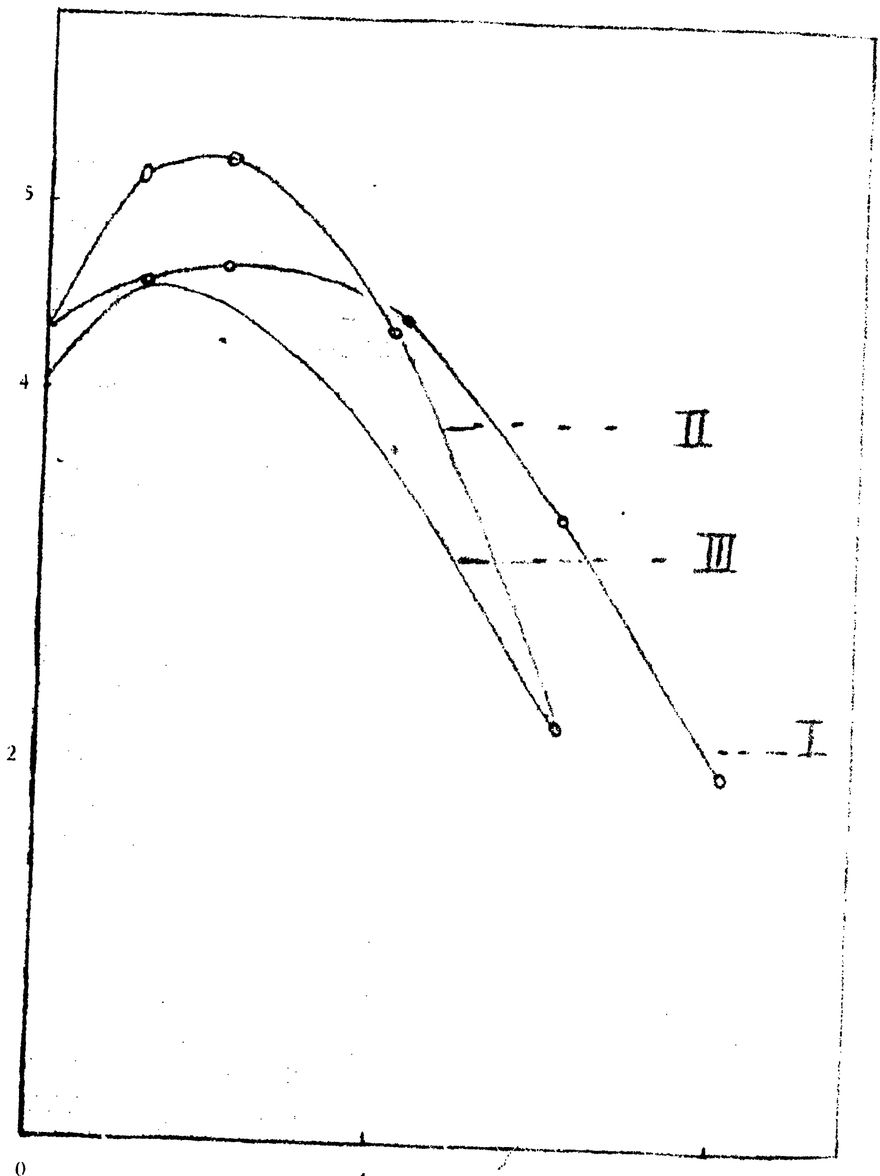


Fig 1

the KCN. In the following table, the effect of dilution of the mastic sol[1] on its coagulation by electrolytes is given.

TABLE XV.

Conc of sol.	66·7 %	53·3 %	26·7 %
Coagulant NaCl milli mole per litre.	450	490	690
Coagulant $BaCl_2$ milli mole per litre.	9·6	9·4	10·4
Coagulant $Al_2(SO_4)_3$ milli mole per litre.	·29	·27	·175

It will be observed from this table that the effect of dilution of the mastic sol on its coagulation by electrolytes is very similar to that of copper ferrocyanide sol. Since the negatively charged copper ferrocyanide sol is also allied to arsenious sulphide sol in many respects, it will be interesting here to compare the effect of mixtures of electrolytes on these sols. The results obtained by us as well as by others are shown graphically in figures I and II.

In the curves, the abscissa represents the amount of the stabilising electrolyte such as $K_4Fe(CN)_6$ etc. added in c.c. The ordinate represents the amount of the coagulating electrolyte.

In Fig. I, the results of Weiser are shown. Nos. I, II, and III respectively gives the results of the mixtures $HCl+MgCl_2$, $LiCl+MgCl_2$ and $LiCl+BaCl_2$.

In Fig. II, the results obtained in this paper are shown. Nos. I, II and III respectively show the curves of $KOH+BaCl_2$, $K_4Fe(CN)_6+KCl$ and $K_4Fe(CN)_6+BaCl_2$.

[1] H. D. Murray, Phil. Mag. p. 401, August. (1922.)

It will be observed from the figures, that the nature of the curves is in all cases very similar, and this denotes that the nature of the action exerted by the different stabilising agents is probably the same. Thus the action of $K_4Fe(CN)_6$ in stabilising a sol of copper ferrocyanide appears to be of the same nature as the action of KCl or HCl on arsenious sulphide sol. Now it is well-known that the stabilising action of $K_4Fe(CN)_6$ is due to the great adsorption of the ferrocyanide ion by copper ferrocyanide, for J. Duclaux[1] has shown that when copper ferrocyanide is precipitated, a great deal of potassium ferrocyanide is also taken up, and it is practically impossible to free copper ferrocyanide from adsorbed potassium ferrocyanide. Another interesting fact in this connection is that the amount of $K_4Fe(CN)_6$ required to coagulate a fixed amount of copper ferrocyanide sol is much greater than that of KCl, the actual results being $K_4Fe(CN)_6$ N/2 2·8 c. cm. and KCl N/4 1·6 c. cm. The coagulating ion in both cases being potassium, these results show the enormous difference in stabilisation which has been brought about by the introduction of the quadrivalent $Fe(CN)_6''''$ ion in place of the monovalent Cl' ion. This stabilisation in presence of mixture of salts cannot be explained on the basis that the addition of $K_4Fe(CN)_6$ decreases the dissociation of KCl, for though the dissociation of KCl may be decreased, the amount of the coagulating ion potassium actually increases very much on the addition of $K_4Fe(CN)_6$. Again a mixture of $K_4Fe(CN)_6$ and $BaCl_2$ shows similar stabilisation and here no decrease in the dissociation of $BaCl_2$ can take place, there being no common ion in the added electrolyte. The stabilisation, therefore, is undoubtedly due to the ferrocyanide ion. Similar results happen in the case of

[1] J. Duclaux, Jour. Chim. Phys. 7, 405-446 (1909).

Opposite to p. 385

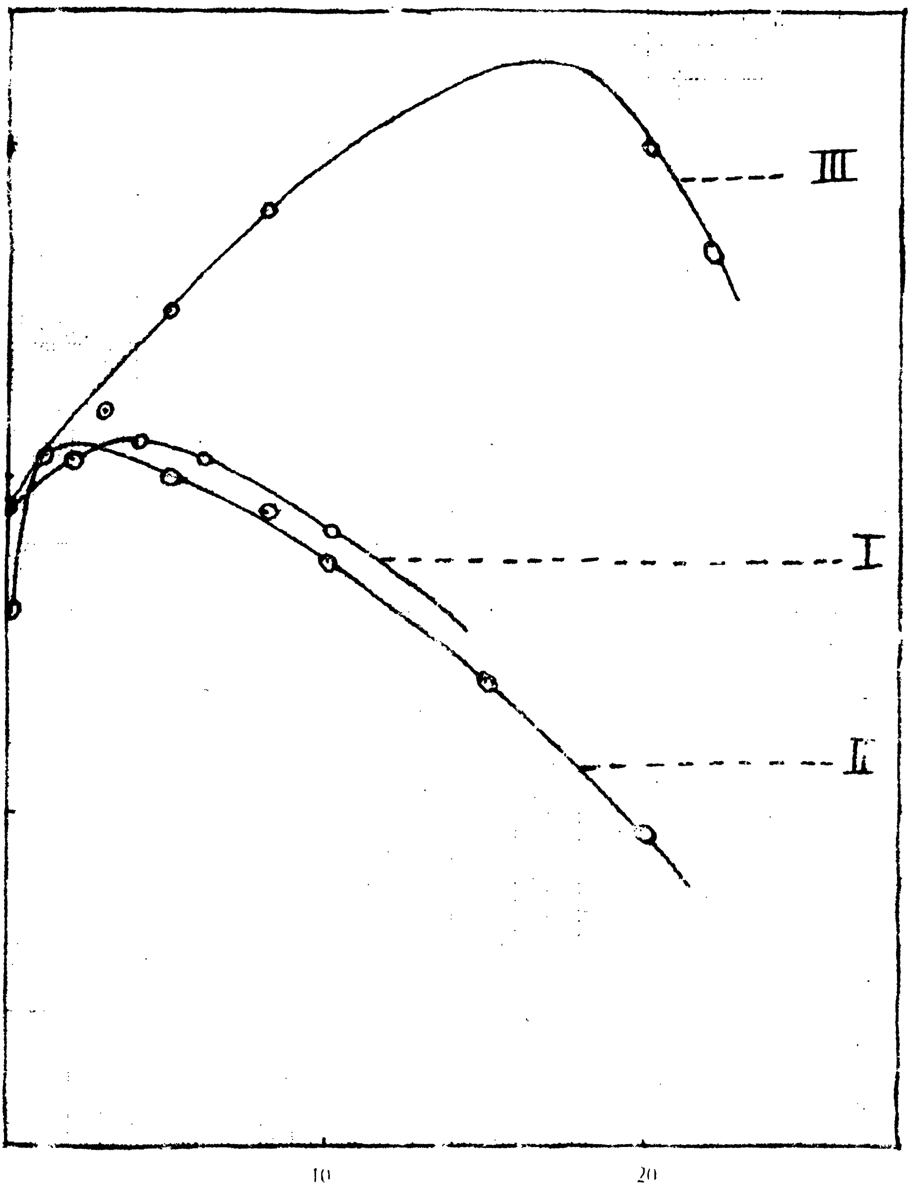


Fig. 2

alkali. In table X, the experimental results with the mixture $KOH + BaCl_2$ has been given. It will be observed that the presence of OH' ions stabilises the negatively charged sol of copper ferrocyanide to a certain extent. It has already been stated that a mastic sol is also stabilised in presence of OH' ion. J. Mukherjee and N. Sen (loc. cit) have shown that colloidal solutions of cupric, mercuric and arsenious sulphides are stabilised by solutions of potassium and sodium sulphides. This stabilising influence has been found for ammonium, potassium, barium, and strontium chlorides and aluminium sulphate. With a trace of pure alkali, sols rich in sulphide are prepared and the OH' ions largely increase the stability of these colloids. It is clear therefore that in these cases, the negative ion is the real stabiliser, and the so-called antagonistic effect is really due to the negative ions of the electrolytes. As a matter of fact, there cannot be any cationic antagonistic action when the mixture $K_4Fe(CN)_6 + KCl$ is used for coagulation, since both electrolytes contain the same cation, and hence in these cases it must be recognised that the antagonistic effect has been mainly due to the anion of potassium ferrocyanide.

Since the precipitation value of an electrolyte for a colloid is that concentration which results in sufficient adsorption of the precipitating ion to neutralise the combined adsorption of the original stabilising ion, and the stabilising ion added with the electrolyte, it is evident that any ion present in the solution, which can either decrease the adsorption of the coagulating ion, or, by being itself adsorbed by the colloid particles increases the charge and hence the stability of the colloid, will act as a stabiliser of the sol towards that particular coagulating ion. It is probable that anions act in the latter way on negatively charged sols, and H° ions also do the same thing on positively charged sols. There is therefore practically no difference

in the nature of the stabilising action exerted by acids on iron, chromium and aluminium hydroxide sols and potassium ferrocyanide, caustic alkali etc., on negatively charged sols. If however the presence of a cation can decrease the adsorption of another coagulating cation, then also the sol may be stabilised. In this case the antagonistic effect will be really cationic. In no case, however, has it been definitely proved that the antagonistic action is only cationic. Thus with the mixture $LiCl+BaCl_2$, and As_2S_3 sol, it has been shows by Weiser (loc. cit.) that the amount of adsorption of either of the ions Li° or $Ba^{\circ\circ}$ is decreased in the presence of each other. But this does not necessarily mean that the sol becomes stable towards $Ba^{\circ\circ}$ ions on the addition of Li° ions. Though the adsorption of each is separately diminished, the total adsorption of both the ions may be equivalent to the adsorption of either Li° or $Ba^{\circ\circ}$ when only one is present. Since the coagulation of the colloid depends primarily upon the charge neutralisation of the colloid, equivalent amounts of Li° or $Ba^{\circ\circ}$ ions will be necessary to discharge the colloid particles. Hence when the sum total of the adsorption of Li° and $Ba^{\circ\circ}$ ions separately expressed in electrochemical equivalents reaches a certain limit, the colloid will be coagulated irrespective of whether the original point of adsorption of $Ba^{\circ\circ}$ ion when it was present alone to coagulate the sol, has been reached or not. In order to support this explanation of the antagonistic action between the ions Li° and $Ba^{\circ\circ}$, it will have to be shown that though one of these ions is not adsorbed appreciably simply by its presence, the adsorption of the other ion is diminished considerably. Also along with this fact it must be observed that by the addition of $LiCl$ to $BaCl_2$ solution, the degree of ionisation of both the electrolytes is thrown back and the concentration of Cl' ions is proportionately increased. The increase in the concentration

of the Cl' ions will mean a stabilisation of the colloid and hence the antagonistic effect which is observed will be the sum of the cationic and anionic effects. This seems also to be the case with such mixtures as $HCl+MgCl_2$, $KCl+SrCl_2$ and $LiCl+MgCl_2$.

It has already been stated that the continual addition of the stabilising agent does not stabilise the colloid to an infinite extent. This is evident from all the curves given in this paper, where stabilisation is found to reach a maximum soon. This is due to the fact that the positive ion of the stabilising agent in the case of negative sols, begins to exert a coagulating effect at higher concentrations of the stabilising electrolyte. This view is extremely well supported by a recently published investigation on the adsorption of electrolytes by colloidal copper ferrocyanide. It has been found by M. Frankert and J. A. Wilkinson[1] that with pure copper ferrocyanide different potassium salts show a gradual change from developing a small amount of acidity with the chloride to large amounts of alkalinity with the ferrocyanide. When the ferrocyanide concentration is gradually increased, the alkalinity which is developed first, gradually changes to acid. On the principle of selective adsorption, the explanation of this phenomenon is that the ferrocyanide ion is strongly adsorbed and the resulting solution thus becomes alkaline. In a particular case, working with 2 gr. of copper ferrocyanide and 2N $K_4Fe(CN)_6$ solution, the total alkalinity developed was equivalent to 200 c. cm. of ·01 N KOH solution. With the ferricyanide solution also, a similar behaviour is observed. The solution is first alkaline due to the adsorption of $Fe(CN)_6'''$ ions, leaving an equivalent amount of KOH in solution. Soon, however, the K ion becomes effective and cuts down the alkalinity

[1] M. Frankert and J. A. Wilkinson, Jour. Phys. Chem., *28*, 651, (1924).

due to the $Fe(CN)'''_6$ and finally overcomes it entirely and the solution turns acid. The experimental curve is therefore the resultant or the difference between the two because one of them tends to develop acid and the other base. This shows that each ion has its own adsorption curve and when several ions are present in the solution, the experimental curve will be the resultant of all the separate curves.

In the foregoing pages, it has been shown that the antagonistic effect between pairs of salts, or the stabilisation of the sol by means of an electrolyte, is in the majority of cases, due to the influence of the ion carrying the same charge as the colloid particles possess. It has also been shown that the stabilisation of some sols on dilution towards some univalent electrolytes may also be explained on the assumption, that the stabilisation is due to the adsorption of the ion charged oppositely to the precipitating ion. These phenomena seem therefore to be related to each other. It is also very probable, as S. Ghosh and N. R. Dhar (unpublished work) suggest, that the phenomenon of so-called "acclimatization" of colloids may be brought in line with these two cases. Since in the phenomenon of acclimatization more electrolyte is necessary to coagulate a colloid when it is added slowly than when it is added rapidly, it is probable that below the precipitation value of the electrolyte, comparatively more of the ion having the same charge as that of the colloid particles may be adsorbed, and thus the stability of the suspension may be proportionately increased. This has also been supposed by H. Weiser who has shown that below the precipitation value of KCl on As_2S_3 sol proportionately more of Cl' ion may be adsorbed by the colloid. This fact may partly explain the "acclimatization," shown by As_2S_3 sol. Similar phenomena are also shown by colloidal platinum and albumin. A similar behaviour

is also observed in the toxin-anti-toxin reaction which is known as the Danysz effect.[1] When a diphtheria toxin is treated with its anti-toxin, the reduction in toxicity depends on the manner in which it is added, *i.e.*, an amount of anti-toxin which is exactly sufficient to neutralise a given amount of toxin when added all at once, is not nearly sufficient to neutralise the same amount of toxin when added little by little with moderate intervals between each addition. The longer the intervals, the greater is the insufficiency. The analogy between the Danysz effect and the acclimatisation phenomenon seems to be very close, for it is probable that in the case of diphtheria toxin and anti-toxin, inactivation is due to electric charge neutralisation. Thus Field and Teague found that diphtheria toxin and anti-toxin migrate distinctly in an electric field. Bechhold also found that diphtheria toxin was slightly weakened at the anode, while the anti-toxin migrated to the cathode. It seems therefore that the stabilisation of a colloid in presence of an electrolyte, the stabilisation of a sol on dilution towards some monovalent electrolytes and the so-called acclimatization of sols, may be all explained by the same theory, and in all these cases, the importance of the ion having the same charge as that of the colloid particles, will, in all probability, have to be recognised as one of the primary factors.

Summary.

(1) An experimental study has been made of the coagulating powers of different electrolytes on a sol of chromium hydroxide and copper ferrocyanide in presence of stabilising ions.

(2) It has been shown that with gradual addition of HCl, the stability of colloidal chromium oxide towards K_2SO_4 and $K_2C_2O_4$, gradually increases and then reaches a maximum. No stabilisation is however observed when the mixture $K_2SO_4 + K_2C_2O_4$ is used.

[1]Compare Taylor, colloid chemistry, (1915), for these biological cases.

(3) With $K_4Fe(CN)_6$ and KCl or $BaCl_2$, the stability of colloidal copper ferrocyanide also gradually increases and on reaching a maximum, decreases. The same behaviour is also observed when a mixture of $KOH + BaCl_2$ is used. With mixtures such as $KCl + BaCl_2$ and $HCl + BaCl_2$, no such stabilisation is observed.

(4) It has been shown that the nature of the stabilisation observed in the case of copper ferrocyanide sol in presence of $K_4Fe(CN)_6$ is similar to that observed by other investigators in the case of As_2S_3 sol and KCl, LiCl or HCl. This is also the case with mastic, As_2S_3, HgS and CuS sols in presence of OH' ions, and $Fe(OH)_3$, $Al(OH)_3$ and $Cr(OH)_3$ sols in presence of acids.

(5) The view has been put forward, that in the majority of cases studied, the so-called antagonistic effect between pairs of salts is really due to the stabilising effect of the ions charged oppositely to that of the precipitating ion. In no case it has been proved that the antagonistic effect is purely cationic, but it is probable that in some cases, a joint action of the anionic and the cationic effect may have been observed.

(6) The stability of the copper ferrocyanide on dilution towards electrolytes has been examined. It has been found that the stability slightly increases towards some monovalent and bivalent electrolytes, but diminishes considerably in presence of trivalent coagulating ions.

(7) It seems probable that the stabilisation of some colloids on dilution, the antagonistic action between pairs of some electrolytes on several colloids, and the phenomena of acclimatization observed with some sols, may be explained by the same theory; and in all these cases, the influence of ions with the same charge as the colloid particles possess, will have to be recognised as of primary importance.

DEPARTMENT OF PHYSICS.

NEW IDEAS ON SPECTRUM ANALYSIS.

By N. K. Sur,

University of Allahabad.

1. INTRODUCTION.

In the year 1859, Kirchoff discovered the principles of spectrum analysis. Sixty-five years have passed since this memorable discovery, yet, to use the language of Newton, it seems as if the whole ocean of spectroscopic knowledge is remaining unexplored, while workers up to this time have only satisfied themselves with the picking up of pebbles on the beach of the vast ocean lying before them.

Kirchoff's discovery directly led to the birth of three new branches in Physical Science. It led to the birth of the science of Astrophysics, that is to say,—the physics of heavenly bodies, which is engaging in America alone twenty-five hundred full-time workers besides a host of amateurs. Light is the only medium which tells us of the island universes in space which we call stars, and hence it is only natural that we can get any information about them only by the analysis of light emitted by them. Kirchoff's theory has been indirectly responsible for the perfection of the laws of black-body radiation, which in the hands of Planck and Einstein has led to the conception of the quantum theory of energy radiation.

Kirchoff's theory tells us that each atom may be compared to a musical instrument. As a musical instrument emits a note characteristic of itself, when tuned properly, so each of the ninety-two different kinds of

atoms emits a series of vibrations in æther. These vibrations do not affect our ears, but our eyes, and we call them light. Light of a particular colour is an electromagnetic disturbance in æther, of which we can measure the exact wave length or frequency. Besides ordinary light, which extends from red (wave length$=7\times10^{-5}$ cm. approximately) to violet (wave length$=4\times10^{-5}$ cm approximately) we may have light of any length longer than the red (infrared) and shorter than the violet (called ultra-violet). Kirchoff was the first to recognise that each different atom gives a number of lines characteristic of itself, so that from the presence of these lines in a specimen which is excited either by heat or electricity, we can detect the element in that specimen. This leads to a very powerful method in chemical analysis for detection of elements. The apparatus by which this analysis is carried out consists of a triangular prism of glass by means of which the line source of light is drawn out into a band called the spectrum; hence this method of analysis is called "spectrum analysis."

We have compared the atom to a musical instrument producing vibrations in æther, but it was apparent even to the earlier workers in spectroscopy that the instrument must have been very complex. A tuning fork emits but a single note. A stringed instrument will emit a fundamental note, with a number of other notes, related to it in simple numerical ratio (called scientifically upper harmonics), but an atom like that of iron emits no less than 4,000 lines in the visible region, and no less than 7,000 lines, if we include those in the infrared and in the ultra-violet regions. Each of these lines corresponds to a different note in æther. Even hydrogen, the simplest of elements, is known to emit many lines. These circumstances led the great American physicist, Henry Rowland, to exclaim that the atom must be more complex than a grand piano!

The labours of spectroscopists after Kirchoff have been mainly directed to the excitation and careful measurement of the wave lenghts of the characteristic lines of different elements. These data are now available in the great dictionary of a spectroscopy compiled by Kayser, Runge, and Konen in Germany in seven volumes, and yet it appears that the subject is in no way exhausted. Every year new additions are being made to our knowledge of the spectra of elements and Kayser and his co-workers are compelled to issue fresh volumes in order that their great dictionary may not get out of date. Photographs of spectra are also available in the famous series edited by Eder and Valenta or Exner and Haschek.

From the year 1880, physicists have been trying to find out some law which connects the different lines of elements, but the first success was reserved for a Swiss school-master named Balmer, who discovered the famous law now known after his name. Hydrogen gives four lines in the visible region; one in the red, one in the green, one in the blue, and one in the violet. Balmer proved that these four lines are expressed by the simple law,—

$$\nu = \frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{m^2}\right)$$

where $m = 3, 4, 5, 6$. The great importance of Balmer's work was at once recognised, and many other scholars turned their attention to this problem. Mention may be made of Rydberg in Sweden, Ritz in Switzerland, Kayser, Runge, and Paschen in Germany, Fowler and Hicks in England.

These investigations, which were purely empirical, stand to the theories of atomic structure in the same relation as the celebrated laws of Kepler stand to the Law of Gravitation. The following sections will give an account of these investigations.

2.—EARLY ATTEMPTS AT GENERALISATION.

Amongst the earliest workers, the foremost names are those of Rydberg and Ritz who occupied themselves with the alkali metals Na, K, Rb, Cs. These elements show spectra having similar constitution. The lines in the case of Na consist of close doublets having a constant frequency difference. Some of these pairs are sharp and others are diffuse in appearance. Rydberg proved that all these sharp lines can be arranged in a series, and the diffuse lines in another series. He also proved that the frequency of each of these lines can be expressed, as the difference of two terms according to the following formulæ:—

$$\nu = R\left[\frac{1}{(2+p)^2} - \frac{1}{(m+s)^2}\right]$$

for sharp series; m varies as 2, 3, 4, 5, etc. and

$$\nu = R\left[\frac{1}{(2+p)^2} - \frac{1}{(m+d)^2}\right]$$

for diffuse series. Here m varies as 3, 4, 5, etc.; p, s, d are fractions having definite values for a definite element. As p has got two values p_1, and p_2, and similarly d has two values d_1, d_2, so that $R\left(\frac{1}{(2+p_2)^2} - \frac{1}{(2+p_1)^2}\right)$ constitute the constant frequency difference. Rydberg further pointed out that the constant R had the same value as that obtained from Balmer's formula.

Ritz carried out the work further and from the analysis of the spectra of the alkaline earths showed that R is very nearly a universal constant. In honour of Rydberg, it is now known as the Rydberg constant. The other alkali elements show a structure similar to that of sodium, but the constant frequency difference increases with the atomic weight. In fact this method can be utilised to calculate very roughly the atomic weight of elements as was done by Runge and Precht when radium was first discoverd.

Besides the sharp and diffuse lines we have got a group of very strong lines including the strongest lines D_1 and D_2 of the whole series. These can be arranged in a series representated by the formula

$$\nu = R\left[\frac{1}{(1+s)^2} - \frac{1}{(m+p_i)^2}\right]$$

where $i=1$ or 2 and $m=2$, 3, etc. This series is known as the principal series of lines. That they are of more fundamental importance than other lines was proved by a series of experiments carried out by R. W. Wood in America. Wood studied the absorption spectrum of Na;—that is to say, he allowed a beam of continuous light to pass through Na—vapour and produced the spectrum of transmitted light by a spectroscope. He found that the spectrum was crossed by dark lines, the wave-lengths of which were exactly the same as those of the lines belonging to the principal series. No line of the sharp and diffuse series was obtained in absorption. Bevan extended the work to the spectra of other alkali elements, and confirmed Wood's observations that only lines of the principal series are absorbed by the vapours of the elements. It may be noted in this connection that the frequency differences of the component lines of the principal series decrease to zero as the limit of the series is approached; also the difference between the limit of the principal series and the two common limits of the diffuse and sharp series is equal to the wave number of the first line of the principal series. This law was simultaneously discovered by Rydberg and Schuster, and is sometimes referred to as Rydberg-Schuster Law.

3.—THE COMBINATION PRINCIPLE.

The principle discovered by Ritz that the frequency of each line can be expressed as the difference of two terms is of great importance in spectroscopy, and is

known as the Combination Principle. Briefly speaking, it states that an atom may possess several groups of series of terms, the terms of one particular group following each other in a natural sequence, and are functions of the successive integer 1, 2, 3, etc. The scheme is best represented in figure 1.

Here *ms* stands for $\dfrac{R}{\left(m+s+\dfrac{\sigma}{m^2}\right)^2}$

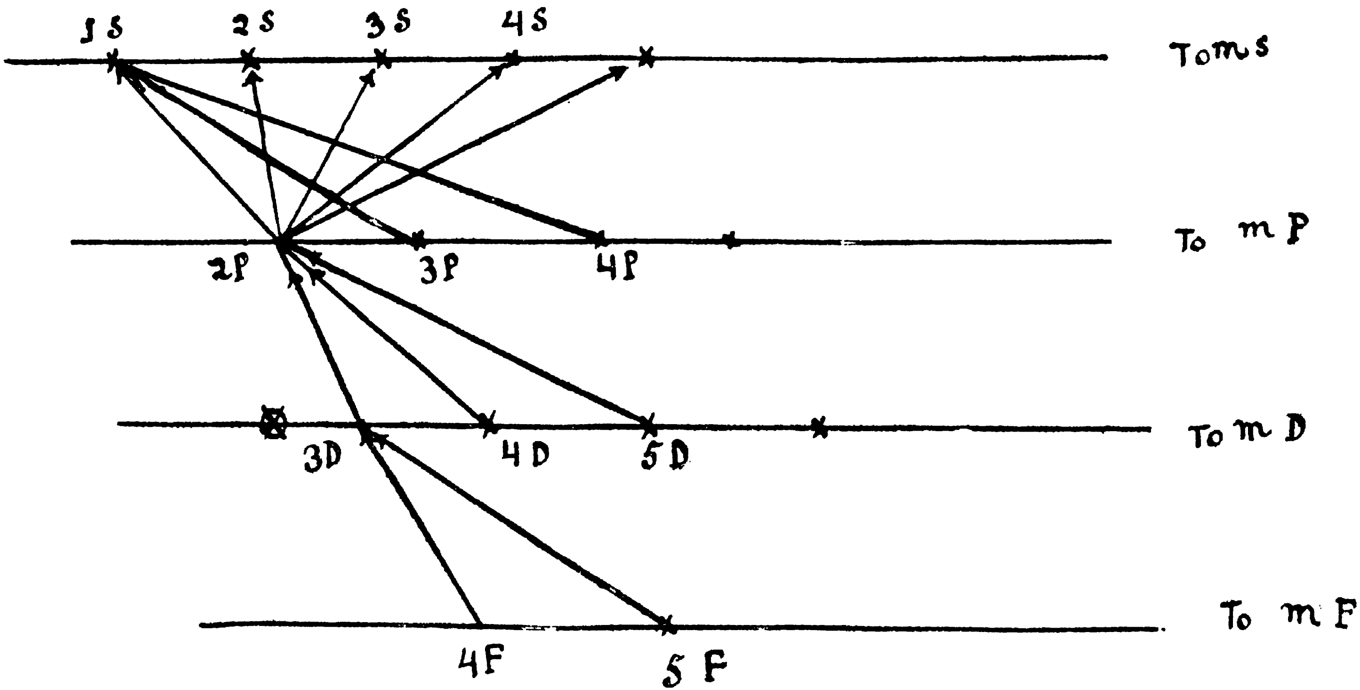
where s and σ are fractions which are constant for all values of m. The formula is only approximate, and many alternative forms have been proposed.

The frequency of a line is obtained by taking the difference of any two terms but all combinations are not possible, the combinations known being shown by arrows in the figure.

From the arrows it will be seen that a term on any one of the horizontal rows can be combined only with a term either immediately on the upper or on the lower row. It cannot be combined with a term on the same row or with terms two steps higher or lower. Again each one of the *p*, *d*, or *f*- terms may be single as in the case of the so-called Par-helium, double as in the case of alkalies or treble as in the case of the alkaline earths, which we shall take up later on. It is to be noted that R retains very nearly the same value for all elements.

4.—BOHR'S THEORY OF THE HYDROGEN SPECTRUM.

We have already mentioned that the labours of Rydberg and Ritz may be compared to those of Kepler who paved the way for Newton. The Newton of atomic physics is Niels Bohr of Copenhagen, who in three epoch-making papers published in the years 1913-14



1S
2S
3S
4S
To ms
2P
3P
4P
To mP
3D
4D
5D
To mD
4F
5F
To mF

first unravelled the mysteries of the atom. According to the older conception, the atom was the ultimate unit of matter. It was supposed to be further indivisible and unalterable in properties. Thanks to the labours of Clausius, Maxwell, and Boltzmann, methods were evolved which enabled the scientists to treat the atom as a real physical entity and not as a purely philosophical curiosity. They could calculate the mass, the radius, and to a certain extent the shape of each individual atom. It was estimated that the mass of the lightest atom of matter, namely, the hydrogen atom was $1{\cdot}65 \times 10^{-24}$ gm. and the radius was of the order of 10^{-8} cm.

In 1895, Sir J. J. Thompson of Cambridge discovered a much smaller constituent of matter *viz.*, the electron. It was found to have a mass of 1/1850 of the atom of hydrogen, and was found to be always associated with a constant negative charge of $4{\cdot}77 \times 10^{-10}$ E. S. U. Thompson found that this electron or the atom of negative electricity was a universal constituent of all matter. The discovery of the electron made it abundantly clear that the atom must be very complex—an opinion which had already been put forward by Rowland. Since all atoms are electrically neutral, they must contain equal quantities of positive and negative electricity, but all attempts to discover the positive electron failed. It was found that all positively charged particles had a mass comparable to that of the atom.

Lord Kelvin and following him, Sir J. J. Thompson were of opinion that the atom consisted of an inner positively charged shell surrounded by a number of electrons. In 1904 Prof. Nagaoka of Japan proposed a very revolutionary model in which it was supposed that the atom might be compared to a planetary system, the positive electricity occupying a very small space in the system just as the Sun does in our solar system and the

electrons revolving at distances like so many planets in their proper orbits. The hypothesis was first put to crucial test by Prof. Rutherford of Cambridge. He bombarded the atom by swiftly moving particles which are obtained from radio-active bodies. They consist of very heavy masses charged with two units of positive electricity moving with enormous velocities. Mass for mass, they constitute projectiles possessing the largest amount of concentrated kinetic energy. Rutherford and his students found that when these particles are sent through the atom, most of them suffer very little deflection, but a minute fraction, say one in two thousand, is returned to the same side from which they are projected. This shows that the centre of the atom must be a source of very intense positive electric forces, and it occupies a very small space. The nuclear theory of the atom, as this conception is frequently styled, has now been placed on a sure foundation. Methods have been developed by means of which we can now measure the central charge as well as can have a rough idea of the space it occupies. We can also find out the number of electrons contained in any atom. These experiments prove that the nuclear charge equals Ae, where A is the ordinal number defining the position of element in the periodic table; an equal number of electrons revolve round this positive nucleus and are grouped in different concentric shells.

When these ideas were just taking a definite shape and have not yet secured general recognition among scientists, Bohr worked out on their basis a theory of hydrogen spectrum, which has now become classical. We have already noted that the spectrum of hydrogen is the simplest and its series regularity is given by

$$\nu = R\left(\frac{1}{2^2} - \frac{1}{m^2}\right)$$

where $m=3, 4, 5, 6$[1]. Bohr supposed that the hydrogen atom consists of a positive nucleus (it may also be considered to be the positive electron or proton, but the essential distinction is to be noted that the mass is about 2,000 times as large as that of the electron) about which the electron revolves in a circular orbit very much in the same manner as the Earth revolves round the Sun. The controlling force is of electrical origin and is equal to $\frac{e^2}{r^2}$ where r is the distance of the electron from the nucleus. This single datum alone does not enable us to determine the orbit; it must be supplemented by further hypothesis. In the case of planetary orbits, the conditions are prescribed by an initial velocity and an initial angle of projection, but this procedure is not possible in the present case. With characteristic boldness, Bohr introduced two hypotheses from the quantum theory which has been developed in Germany by Planck and Einstein. This theory states that radiant energy is also atomic in structure, it being propagated in space in concentrated cells, having the energy-content $h\nu$ where ν is the frequency of light vibration. Nicholson had noted that h has got the same dimensions as moment of momentum, torque or turning couple. Bohr grasped the idea and put this turning couple of the electron round the nucleus equal to $\frac{nh}{2\pi}$ where n is an integer. This enabled him to calculate the energy of the system which came out to be $W_n = -\frac{2\pi^2 e^4 m}{h^2} \cdot \frac{1}{n^2}$.

Now n is a number which is rather used arbitrarily. Bohr supposed that the electron can rest in dynamical equilibrium

[1] 35 lines corresponding to values of m higher than 6 have been obtained by Mitchell, and by Evershed in the solar chromosphere, and about 20 have been obtained in the laboratory by Wood.

in an infinite number of meta-stable orbits characterised by the letters $n=1, 2, 3$ etc., the radius of an orbit being proportional to $a_0 n^2$ where $a_0 = \frac{h^2}{4\pi^2 e^2 m}\cdot$ It will be seen that the energy diminishes as n diminishes. When the electron falls from any one of the outer to any one of the inner orbits it loses its energy which is propogated in space in the form of a pulse of light of energy $h\nu = W_f - W_i$, W_f being the energy in the final state and W_i in the initial state. Substituting the value of W.

$$\nu = \frac{2\pi^2 e^4 m}{h^3}\left(\frac{1}{n^2} - \frac{1}{n'^2}\right)$$

if we put $n=2$, the formula reduces to the same form as that of Balmer. It now remains to be seen if the constant $\frac{2\pi^2 e^4 m}{h^3}$ has the same value as the Rydberg constant. Now the Rydberg constant is obtained in a purely empirical way from spectroscopic data. The constant occurring in the term $\frac{2\pi^2 e^4 m}{h^3}$ namely e, m, h are obtained from quite different series of experiments, e being obtained from electrostatic experiments of Thomson and Millikan, e/m being obtained from deflection of cathode particles in crossed electric and magnetic fields, and h is obtained from measurements of radiation from a perfectly black body. These phenomena are entirely unconnected, yet Bohr found that the expression $\frac{2\pi^2 e^4 m}{h^3}$ came out to have exactly the same value as the Rydberg constant R. A great trait of master minds is to find out the fundamental unity between disconnected phenomena, and Bohr has surely scored a great triumph in connecting so many diverse branches of physics as electron theory, spectroscopy and the theory of radiation, thus placing the electrical theory of matter on a firm and unassailable basis. It is not possible here to give even a summary account of the great revolution

in ideas which has been brought about by Bohr's grand discovery. We shall confine ourselves only to spectroscopy.

Bohr's theory explains not only the hydrogen spectrum but gives a general explanation of spectra of all elements, and enables us for the first time to explain the Combination Priniciple. An atom of sodium consists of a nuclear charge of 11 with eleven electrons moving round it. It is believed that the outer-most electron revolves at a greater distance than the others, and determines the chemical and spectroscopic properties of sodium. This electron possesses a number of stable orbits similar to that of hydrogen, but it is not possible to calculate the form of these orbits nor the energy—content in them, because the problem is one of great mathematical difficulty. The case of hydrogen is very simple because we have to find out the motion of one single electron about the nucleus. Here we have to find out the motion of the electron in the combined field of the nucleus and ten electrons. This is the celebrated problem of *n* bodies which has defied the attempt of all mathematicians for two centuries and a half since the days of Newton.

Still a sort of general explanation was given by Bohr and fully developed by Prof. Sommerfeld of Munich. Extending the idea developed in the theory of hydrogen spectrum, Bohr maintained that the energy of any particular line is simply the difference between the energy contents in the two stable orbits. This explains the combination principle in a very admirable manner. Sommerfeld showed that the orbits, even in the case of hydrogen, may not only be circular but may also be elliptic, just as the orbits of planets may be ellipses of varying eccentricity. The mean angular velocity of the electron in the orbit is determined by a quantum number k, which is known as the rotational quantum number, but the

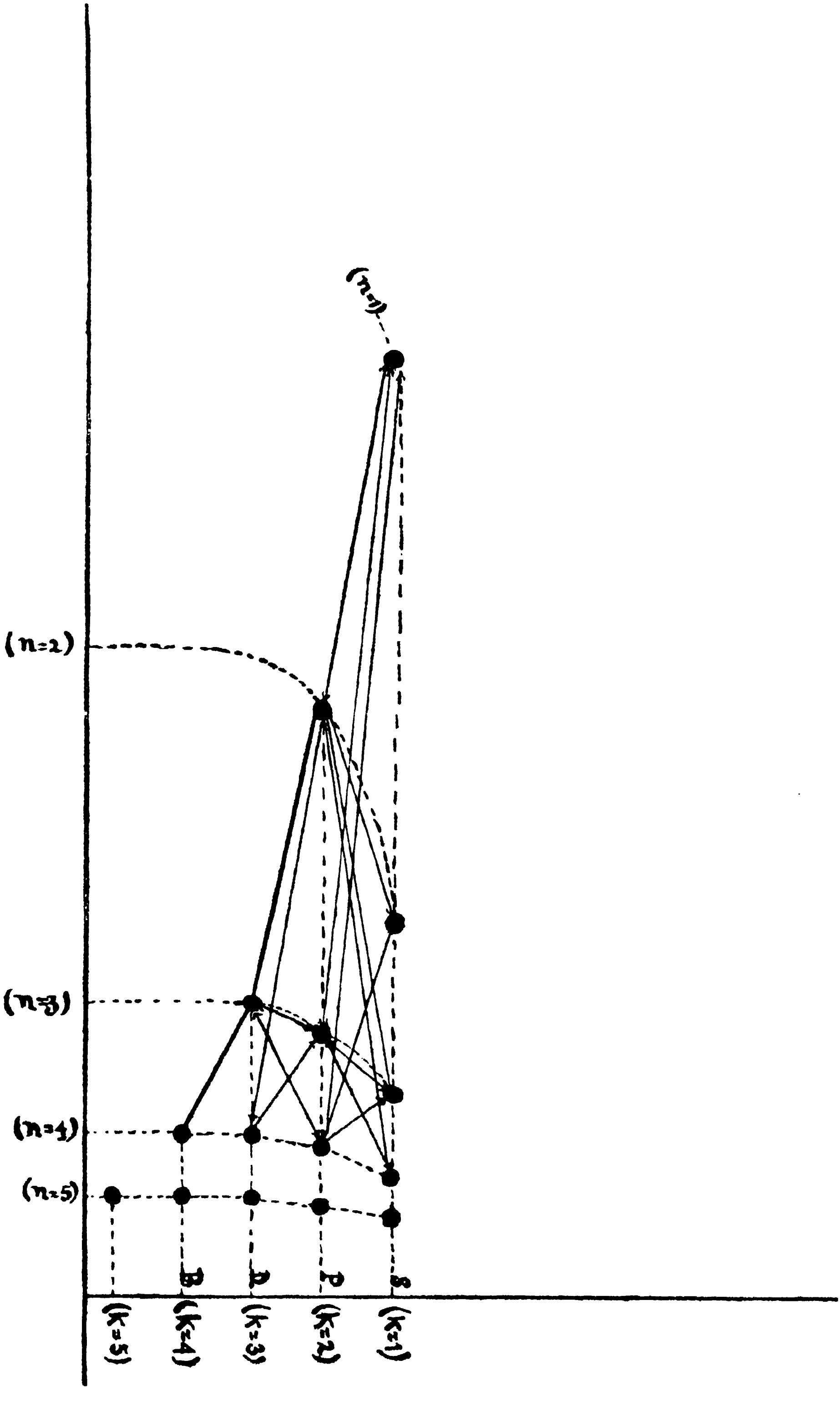
eccentricity of the orbit is determined by another quantum number n' the energy being equal to (in the case of hydrogen) $\frac{Rh}{(k+n')^2}$.

Extending the idea to the alkali elements, Sommerfeld could easily explain the multiplicity of terms in the sodium atom. Each term now represents the energy in a definite meta-stable orbit and every group of terms correspond to one group of orbits having one factor in common. According to Sommerfeld all the s- terms have got the rotational quantum number 1, all the p terms have the rotational number 2, the d terms 3 etc. The combination diagram is now reduced to a diagram of energy levels, characterised by the quantum numbers, n, k, where n is the total quantum number and k is the azimuthal quantum number. (Fig. 2.)

It may be noted that Sommerfeld's theory offers no explanation for the multiplicity of the p, d, or f terms *i. e.*, why we have two p's, p_1 and p_2, two d's, d_1 and d_2 etc., in the case of the alkalies.

5.—SPECTRA OF ALKALINE EARTHS.

It is now our object to show how these ideas have helped us to elucidate the regularities in the spectra of elements of the other groups. This is not an easy matter, because the number of terms is enormously increased, as we go to elements of the higher groups of the periodic table. Long before the advent of Bohr's theory, the spectra of the alkaline earths had been classified into series. It was found that the lines could be grouped in three distinct classes:—a triplet series, a singlet series, and a doublet series. The singlet series is just like that of hydrogen, every line being single. The doublet series has the same constitution as the lines of the alkalies, two lines always occurring in pairs separated


(n=1)
(n=2)
(n=3)
(n=4)
(n=5)
B
D
P
S
(K=5)
(K=4)
(K=3)
(K=2)
(K=1)

by a constant frequency difference. Like those of alkalies they could be classified in groups of *s*- terms. The triplet series is more difficult to explain. Briefly speaking, three lines always occur associated together with constant frequency differences between them. Analysis shows that there is one set of *s*- terms, three sets of *p*- terms, three sets of *d*- terms, and three sets of *f*- or *b*- (Bergmann) terms. Combination between the terms is always regulated by certain laws. We shall speak of these combinations later on.

Before proceeding further, it is necessary to explain the connection between different groups. The lines of the singlet and the triplet series are found to be always associated together. They occur at the lowest stimulus, and they have got the same Rydberg number R. But the doublet series stand on quite a different level. Lockyer first showed that these lines are obtained with a stimulus greater than that required to excite the lines of the singlet and the triplet series, and the Rydberg number is not R but 4R[1]. The explanation was given by Bohr. According to him these lines are not due to the ordinary calcium atoms, but are due to atoms which have lost one valency electron and have acquired a net positive charge of one unit. The motion of the electron in such a system takes place under a net nuclear charge of two units, and remembering that the Rydberg number is equal to $\frac{2\pi^2 e^2 E^2 m}{h^3}$, we see that the Rydberg number is equal to 4R if we put $E=2e$. Here E denotes the charge of the nucleus. The conditions of excitation also support this view. It must be sufficiently strong to tear off one electron and excite the remaining valency electron to luminescence. The doublet series can

[1] This fact was first discovered by Prof. A. Fowler in the analysis of the spark spectrum of magnesium, and later extended by him to the doublet spectra of calcium, barium, and strontium.

therefore be treated differently from the singlet and triplet systems for it is due to an essentially different system. In this connection Sommerfeld and his student Kossel arrived at a generalisation of far reaching consequence and destined to play a great part in the future development of spectroscopy. Now calcium is different from potassium in having two valency electrons while potassium has got one. But when calcium loses one electron, it becomes similar in constitution to potassium with the difference that the net nuclear charge is now two units. Therefore, according to them, the spectrum of Ca^+ will be similar in constitution to that of K, but the Rydberg number is 4R instead of R. Generalising this conclusion, they formulated the Displacement Law in spectroscopy, which may be thus stated:—When an element loses one, two or more electrons, then as far as its spectrum is concerned, it becomes similar in constitution to that of the element preceding it in the periodic table by one, two or more positions. Thus:—

The spectrum	of	Ca^+	is	similar	to	that	of	K
„	„	Al^+	„	„	„	„	„	Ca ($R=4N$)
„	„	Al^{++}	„	„	„	„	„	K ($R=9N$)
„	„	Si^+	„	„	„	„	„	Al ($R=4N$)
„	„	Si^{++}	„	„	„	„	„	Ca ($R=9N$)
„	„	Si^{+++}	„	„	„	„	„	K ($R=16N$).

These predictions were made by Kossel and Sommerfeld in the year 1919, and they have been fully verified in recent years by the works of Fowler on the spectrum of Si^+, Si^{++}, Si^{+++}, and by the works of Paschen on the spectra of Al^+, Al^{++}.

Recent works by Millikan, Meggers and Russell, confirm the validity of the law regarding the spectra of Sc^+, Ti^+, V^+, Cr^+, Fe^+, &c.

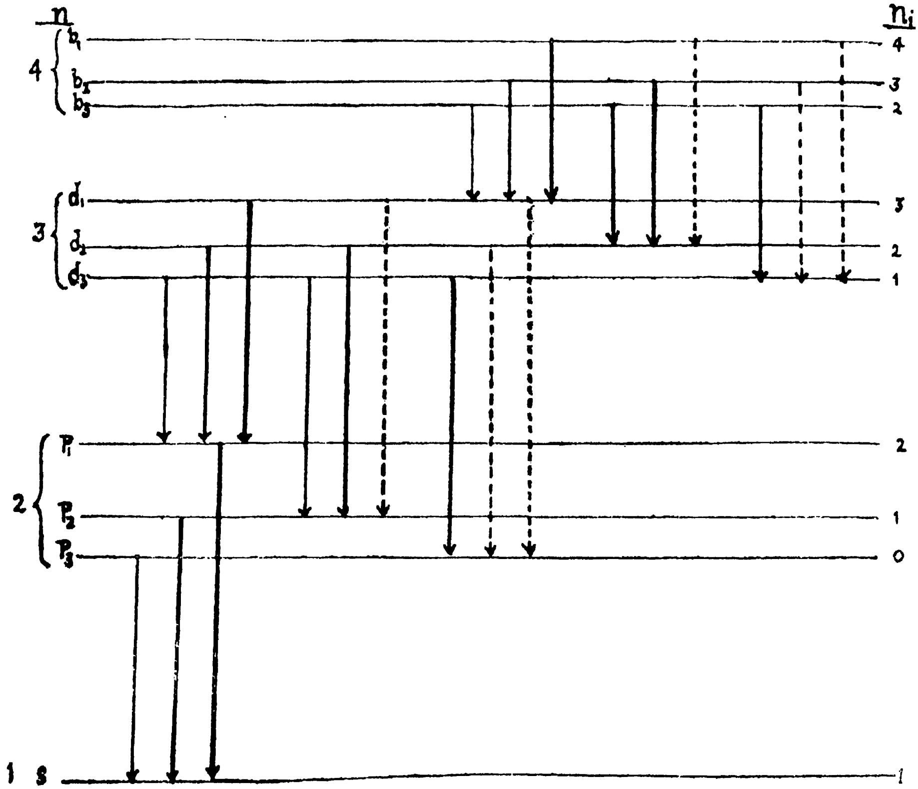


Fig. 3

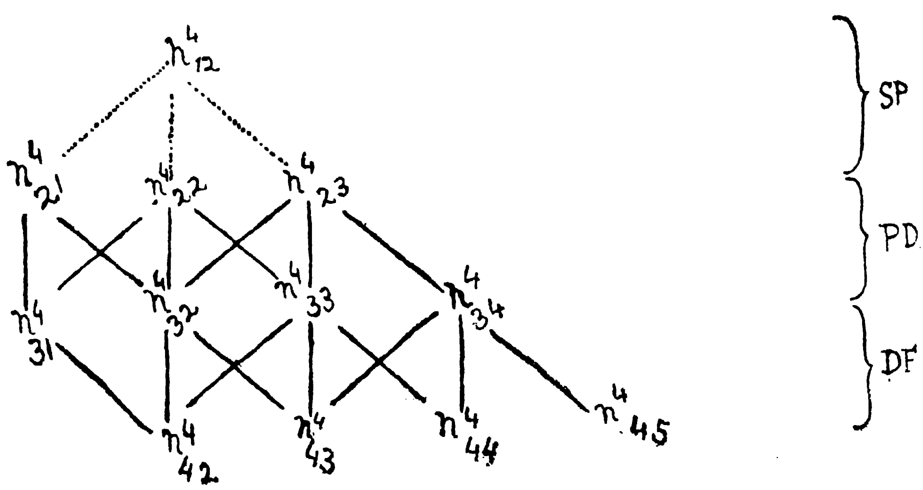


Fig. 4

Turning now to the spectrum of calcium proper, we have already stated that it can be grouped in a triplet and singlet system with inter-combination between the two. The scheme of the composite triplets is shown in the figure 3.

It is to be noted that $p_1 < p_2 < p_3$ and $d_1 < d_2 < d_3$ and the combination between the p and d terms occur in the following manner:—

$p_1 - d_1$	chief line
$p_1 - d_2$	Satellite
$p_1 - d_3$	,,
$p_2 - d_2$	chief line
$p_2 - d_3$	Satellite
$p_3 - d_3$	,,

The combination may be schematically thus represented:—

	d_3	d_2	d_1
p_3	×		
p_2	×	×	
p_1	×	×	×

The crosses represent the lines actually observed.

The *df* combination is thus represented:—

	f_3	f_2	f_1
d_3	×		
d_2	×	×	
d_1	×	×	×

The following illustration of the above are taken from spectra of calcium and barium from Fowler's Report on Series in Line Spectra.

Calcium.

		11556·4	11552·6	11547·0
		d_3	d_2	d_1
34146·9	p_3	(9) 22590·5 4425·43		
34094·6	p_2	(8) 22538·2 4435·67	(9) 22542·0 4434·95	
33988·7	p_1	(3) 22432·3 4456·61	(5) 22436·1 4455·88	(9) 22441·7 4454·77

Barium.

		7426·8	7412·8	7398·6
		f_3	f_2	f_1
32995·6	d_3	(8 R) 25568·8 3909·92		
32814·1	d_2	(6) 25387·3 3937·88	(8 R) 25401·3 3935·72	
32433·0	d_1	? 25006·2 3997·92	(6) 25020·2 3995·66	(10 R) 25034·4 3993·40

6.—MULTIPLETS.—CATALAN'S WORK.

The next great achievement in spectroscopy is the classification of the lines of manganese, which was completed by Dr. Catalan of the University of Madrid in Spain working in the laboratory of Prof. Fowler. Catalan was the first to introduce effectively the idea of multiplets, which is a generalisation of the type represented by the *pd* combination in Calcium. He found that the number of associated terms in the *p* or *d* groups may be as large as 4, 5, 6 etc., in the case of elements of higher groups of the periodic table instead of 3 as in the case of Calcium. Catalan's idea was taken up vigorously in Germany, and America, and the classification of the spectra of chromium, and molybdenum by Catalan himself, vanadium and iron by Laporte in Germany and of titanium by Kiess and Kiess in America followed in quick succession. As the laws of these combinations have been very elegantly worked out in a paper by Lande, we shall not speak of these works in advance, but proceed straight to an exposition of Lande's theory. It might be mentioned that the theory is the result of a mass attack on the part of the Sommerfeld school, including, besides Prof. Sommerfeld himself, his students Heissenberg, Lande, Gieseler, Laporte and others. They introduced the idea of an inner quantum number to explain the combination of sets of terms belonging to different groups. Thus according to this scheme, the distinction between p_1, p_2, p_3.........terms lie in their having different inner quantum numbers; these inner quantum numbers define the motion of the valency electron as influenced by the inner ring of electrons, and are shown to have a very intimate connection with the intra-atomic magnetic field. They are therefore of great importance in determining the Zeeman splitting up the lines in the presence of an outer magnetic field, but space does not

permit us to speak in detail of the application of these conceptions to the problem of anamolous Zeeman effect. For p_1, $j=2$, for p_2, $j=1$; for p_3, $j=0$; if j denotes the inner quantum number. For d_1, d_2, d_3, the values of j are 3, 2, 1 respectively. Thus modifying the previous scheme we can re-write it as:—

j	d_3 1	d_2 2	d_1 3
p_3, 0	×		
p_2, 1	×	×	
p_1, 2	×	×	×

Lande introduces the notation n^r_{kj} to denote the characteristics of a particular term. The running number n represents the total quantum number, k the rotational or azimuthal quantum number, j the inner quantum number and r denotes the trunk quantum number or the permanent multiplicity of the term. Thus for singlets, $r=1$, for doublets $r=2$, for triplets $r=3$, and so on. The Principle of Selection, governing the combination between different terms, for the various quantum numbers is thus represented:—

$$r \begin{array}{l} \nearrow r+2 \\ \longrightarrow r \\ \searrow r-2 \end{array}$$

$$k \begin{array}{l} \nearrow k+1 \\ \searrow k-1 \end{array}$$

$$j \begin{array}{l} \nearrow j+1 \\ \longrightarrow j \\ \searrow -1 \end{array}$$

with the exclusion of $j=o \longrightarrow j=o$

The set of terms in each one of the s, p, d, or f groups are represented in the following scheme:—

TABLE I.

The Terms. n^{r}_{kj}

	Singlets.	*Triplets.*	*Quintets.*
	n^{1}_{10}	n^{3}_{11}	n^{5}_{12}
Odd	n^{1}_{21}	$n^{3}_{20}\ n^{3}_{21}\ n^{3}_{22}$	$n^{5}_{21}\ n^{5}_{22}\ n^{5}_{23}$
multiplets.	n^{1}_{32}	$n^{3}_{32}\ n^{3}_{32}\ n^{3}_{33}$	$n^{5}_{30}\ n^{5}_{31}\ n^{5}_{32}\ n^{5}_{33}\ n^{5}_{34}$
	n^{1}_{43}	$n^{3}_{42}\ n^{3}_{43}\ n^{3}_{44}$	$n^{5}_{41}\ n^{5}_{42}\ n^{5}_{43}\ n^{5}_{44}\ n^{5}_{45}$
	Doublets.	*Quartets.*	*Sextets.*
Even	n^{2}_{11}	n^{4}_{12}	n^{6}_{13}
multiplets.	$n^{2}_{21}\ n^{2}_{22}$	$n^{4}_{21}\ n^{4}_{22}\ n^{4}_{23}$	$n^{6}_{22}\ n^{5}_{23}\ n^{6}_{24}$
	$n^{2}_{32}\ n^{2}_{33}$	$n^{4}_{31}\ n^{4}_{32}\ n^{4}_{33}\ n^{4}_{34}$	$n^{6}_{31}\ n^{6}_{32}\ n^{6}_{33}\ n^{6}_{34}\ n^{6}_{35}$
	$n^{2}_{44}\ n^{2}_{44}$	$n^{4}_{42}\ n^{4}_{43}\ n^{4}_{44}\ n^{4}_{45}$	$n^{6}_{41}\ n^{6}_{42}\ n^{6}_{43}\ n^{6}_{44}\ n^{6}_{45}\ n^{6}_{46}$

TABLE II.

Comparison between the old and new notation.

ns	np	nd	ns	np_1	np_2	nd_1	nd_2	ns	np_1	np_2	np_3	nd_1	nd_2	nd_3
n^{1}_{10}	n^{1}_{21}	n^{1}_{32}	n^{2}_{11}	n^{2}_{22}	n^{2}_{21}	n^{2}_{33}	n^{2}_{32}	n^{3}_{11}	n^{3}_{22}	n^{3}_{21}	n^{3}_{20}	n^{3}_{33}	n^{3}_{32}	n^{3}_{31}

Lande also gives a rule which enables us to determine the ratio between the different frequency differences of a particular set of terms. That there is some regularity was noticed even by earlier workers. We shall illustrate it from the alkaline-earth metals.

Thus for Mg, $2p_2 - 2p_1 = 40{\cdot}9 : 2p_3 - 2p_2 = 19{\cdot}2 :: 2 : 1$

Ca, $2p_2 - 2p_1 = 105{\cdot}9 : 2p_3 - 2p_2 = 52{\cdot}2 :: 2 : 1$

Sr, $2p_2 - 2p_1 = 394{\cdot}2 : 2p_3 - 2p_2 = 186{\cdot}8 :: 2{\cdot}1 : 1$

Ba, $2p_2 - 2p_1 = 878{\cdot}2 : 2p_3 - 2p_2 = 370{\cdot}4 :: 2{\cdot}3 : 1$

If we take the difference between the corresponding d terms we have,

$$\text{Ca, } 3d_2 - 3d_1 = 21{\cdot}5 : 3d_3 - 3d_2 = 13{\cdot}6 :: 3 : 2$$
$$\text{Sr, } 3d_2 - 3d_1 = 99{\cdot}6 : 3d_3 - 3d_2 = 59{\cdot}3 :: 3{\cdot}4 : 2$$
$$\text{Ba, } 3d_2 - 3d_1 = 380{\cdot}8 : 3d_3 - 3d_2 = 181{\cdot}6 :: 4{\cdot}2 : 2$$

Generalising this scheme, Lande proposed that for even multiplets

$$r = 2, 4, 6, \text{ etc.}$$

$$(n^r_{k1} - n^r_{k2}) : (n^r_{k2} - n^r_{k3}) : (n^r_{k3} - n^r_{k4})$$
$$= \frac{(2^2 - 1^2)}{2} : \frac{(3^2 - 2^2)}{2} : \frac{(4^2 - 3^2)}{2} = \tfrac{3}{2} : \tfrac{5}{2} : \tfrac{7}{2} = 3 : 5 : 7$$

and for odd multiplets $r = 1, 3, 5$, etc.

$$(n^r_{k0} - n^r_{k1}) : (n^r_{k1} - n^r_{k2}) : (n^r_{k2} - n^r_{k3})$$
$$= \{(1+\tfrac{1}{2})^2 -)\tfrac{1}{2})^2\} : \{(2+\tfrac{1}{2})^2 - (1+\tfrac{1}{2})^2\} : \{(3+\tfrac{1}{2})^2 - (2+\tfrac{1}{2})^2\}$$
$$= 1 : 2 : 3$$

An illustration of Lande's classification is afforded in the spectrum of manganese. The spectrum of manganese according to Catalan consists of quartet, sextet and octet groups. Taking the quartet system we represent the combinations in the following diagram :—

The illustrations are afforded in the following tables :—

f- terms.

				118·33		172·74		234·74	
			j	n^4_{42} 2		n^4_{43} 3		n^4_{44} 4	n^4_{45} 5
d- terms		n^4_{31}	1	(4) 20995·81					
	99·31								
		n^4_{32}	2	(4) 21095·12		(5) 20976·71			
	170·39								
		n^4_{33}	3	(2) 21265·43		(5) 21147·10		(6) 20974·25	
	252·38								
		n^4_{34}	4			(1) 21399·57		(7) 21226·83	(8) 20992·09

Lande's rule is thus illustrated:—

$$252{\cdot}6 : 170{\cdot}3 : 99{\cdot}3 = \frac{7 : 4{\cdot}8 : 2{\cdot}8\text{.........observed}}{7 : 5 : 3\text{...calculated according to Lande}}$$

$$234{\cdot}7 : 172{\cdot}8 : 118{\cdot}4 = \frac{9 : 6{\cdot}6 : 4{\cdot}5\text{.........observed}}{9 : 7 : 5\text{...calculated according to Lande}}$$

Another illustration is given here from the spectrum of iron, classified by Laporte into triplets, quintets and septets.

Quintet system

d': 90·0, 184·2, 288·1, 416·0

p	j	n^5_{30} 0	n^5_{31} 1	n^5_{32} 2	n^5_{33} 3	n^5_{34} 4
n^5_{21}	1	(40) 28754·6	(60r) 28844·6	(50r) 29028·8		
263·7						
n^5_{22}	2		(40) 28880·9	(70r) 28765·1	(75r) 29053·2	
412·9						
n^5_{23}	3			(20) 28352·1	(100r) 28640·3	(150r) 29056·3

Interval Rule :—

$$\Delta d^1 ;\ 89{\cdot}9 : 184{\cdot}1 : 288{\cdot}1 : 416{\cdot}0 = \frac{1 : 1{\cdot}8 : 2{\cdot}7 : 4\text{...observed}}{1 : 2 : 3 : 4\text{...calculated}}$$

$$\Delta p_1 ;\ 263{\cdot}7 : 412{\cdot}9 = \frac{1{\cdot}9 : 3\text{..................observed}}{2 : 3\text{...calculated according to Lande}}$$

The intensity rule may be introduced at this stage. It states that among the three possible transitions of *j* the strongest line arises from the change in *j* which parallels the change in *k*, and the intensity diminishes in

the order that the transition of j deviates from that of k. This rule is also well illustrated in the above tables.

It is not possible to give a detailed account of the works which have been done in recent years, *viz.*, the work of Catalan on Mn, $Mn,^+$ Cr, $Cr,^+$ Mo, Sc, and Sc^+ (the last two being fragmentary), the work of Laporte on vanadium and iron, and the work of Kiess and Kiess on titanium. The spectra of the elements in the third row of the periodic table have been more or less completey classified with the exception of cobalt and nickel. The multiplicity which have been observed are presented below.

K	Ca	Sc	Ti	Va	Cr	Mn	Fe
Doublets.	Singlets. Triplets.	Doublets. Quartets.	Singlets Triplets. Quintets.	(Doublets). Quartets Sextets.	(Singlets) Triplets Quintets Septets.	(Doublets) Quartets Sextets Octets.	(Singlet) Triplets Quintets Septets (Nonets).

The system enclosed within brackets have not yet been observed.

7.—THE IONISATION POTENTIAL.

In the early work on spectral series, it was supposed that the biggest term corresponding to the lowest or normal energy level was always an s- term, the p-, d-, f- and q- terms successively decreasing in value. From the highest term number multiplied by h, the ionisation potential in volts, or the amount of energy which must be given to the outermost electron to separate it from the atom, can be easily obtained from the usual relation,

$$V = \frac{h\nu}{e}$$

The view that the s- term is the biggest term, can no longer be maintained, in view of recent work. It holds

quite well for the elements of the first and second groups of the periodict able, consisting of both odd and even groups, and they have been verified by the experiments on ionisation potential, initiated by Franck and Hertz in Germany, and carried out by Foote, Mohler, Horton, Davies and others. The following tables illustrate the truth of this law.

Resonance and Ionisation Potential.

Group I.

ment.	Atomic No.	Series Notation.		Volts. Computed.	Observed.
Li	3	1s	43486	5.368	
		$1s-2p_1$	14903	1.840	
Na	11	1s	41449	5.116	5.13
		$1s-2p_1$	16973	2.095	2.12
K	19	1s	35006	4.321	4.1
		$1s-2p_1$	13043	1.610	1.55
Cu	29	1s	62308	7.692	
		$1s-2p_1$	30784	3.800	
Rb	37	1s	33689	4.158	4.1
		$1s-2p_1$	12817	1.582	1.6
Ag	47	1s	61696	7.542	
		$1s-2p_1$	30473	3.762	
Cs	55	1s	31405	3.877	3.9
		$1s-2p_1$	11732	1.448	1.48
Au	79	1s	70000 (?)	8 to 9 (?)	
		$1s-2p_1$	41174	5.1	

Group II.

Mg	12	1S	61672	7.613	7.75
		$1S-2p_2$	21871	2.700	2.65
		$1S-2P$	35051	4.327	4.42
Ca	20	1S	49305	6.087	6.01
		$1S-2p_2$	15210	1.878	1.9
		$1S-2P$	23652	2.920	2.85
Zn	30	1S	75767	9.353	9.3
		$1S-2p_2$	32502	4.012	4.18
		$1S-2P$	46745	5.771	5.65

Groups II

Element	Atomic No.	Series Notation.		Volts Computed	Volts Observed.
Sr	38	1S	45926	5·670	
		$1S-2p_2$	14504	1·791	
		$1S-2P$	21698	2·679	
Cd	48	1S	72539	8·955	8·92
		$1S-2p_2$	30656	3·784	3·95
		$1S-2P$	43692	5·394	5·35
Ba	56	1S	42029	5·188	
		$1S-2p_2$	12637	1·560	
		$1S-2P$	18060	2·230	
Hg	80	1S	84178	10·392	10·2
		$1S-2p_2$	39413	4·866	4·76
		$1S-2P$	54066	6·674	6·45
Ra	88	1S	4 -5000(?)	5 – 5·5(?)	
		$1S-2p_2$	12500(?)	1·5(?)	
		$1S-2P$	20700(?)	2·6(?)	

It will be noticed that in the case of the alkaline earths it is the 1S-, term of the singlets which has the largest value. The resonance lines or the lines which appear with the least amount of excitation are the lines $1s—2p_1$ or $1s—2p_2$ in the case of alkalies and $1S—2p_2$ and $1S—2P$ in the case of the elements of the second group. They are also the "raies ultimes" or the ultimate lines which are obtained with the least amount of material. But the law that the 1S term has got the highest value does not seem to be true in the case of the elements of the other groups. In the case of the elements of the third group, which have already been shown to be classified into doublet series, the terms having the highest value are $2p_1$ and $2p_2$, the biggest s- term having a much smaller value, as the following table shows:—

Element.	1s.	$2p_1$.	$2p_2$.
Al	22933·27	48168·84	46280·91
Ga	23591·5	47553·8	48379·8
In	22294·8	44455·3	46667·9
Tl	22786·7	41471·5	49264·2

It was first supposed that the real 1s- term was still undiscovered and that it had a value very slightly exceeding the $2p$- terms, so that the resonance lines were in the infra-red, but this supposition has not been verified. The absorption experiments could have decided the point, but all these elements have the singular property of possessing high boiling points and rather low melting points, so that to obtain sufficient vapour for absorption experiments, very high temperatures were necessary, which were difficult to obtain except probably in the case of thallium. But recently absorption experiments have been carried out by Grotrian, Gibson (in the case of thallium) and Caroll, and in this laboratory which show that at least in the case of thallium that the lines first to come out in absorption are $2p_1-ms$ and $2p_2—ms$ so that little doubt now remains that $2p_1$ and $2p_2$ are the highest terms fixing the ionisation potential. These results have been also verified by the experiments of Foote, Ruark and Mohler.

Works on the other elements, which have been already mentioned, have now amply proved that the 1s terms can no longer be maintained to be the highest term. Of course in the case of Mn, Cr, and Mo, Catalan has found that the highest terms are 1S- terms, but in the case of vanadium, the lines of which can be grouped into a quartet and sextet series, the highest term is represented by an f- term of the quartet system, and the resonance lines occur with a combination of this f- term with a g- term. Grotrian however suspects that there is besides a doublet series. In the case of iron, the lines of which have been carefully studied by Laporte, the highest terms have been found to be five d- terms belonging to a quintet system. The "raies ul times" of iron belong to a combination of these d terms with either p or f- terms as illustrated in the

following table. It may be noted here that Grotrian, Angerer and Joos have also obtained these lines in absorption.

		$k=3$				
			89·91	184·15	288·08	415·92
	j	0	1	2	3	4
	1	80 R 3745·900 26688·31	80 R 3733·319 26778·22	20 R 3707·828 26962·43		
106·76						
	2		125 R 3748·264 26671·45	100 R 3722·565 26855·57	20 R 3683·056 27143·66	
164·89						
$k=4$	3			150 R 3745·563 26690·69	150 R 3705·567 26978·76	20 R 3649·308 26394·67
227·86						
	4				200 R 3737·135 26750·88	100 R 3679·915 27166·82
292·29						
	5					300 R 3719·938 26874·53

In view of these discrepancies Grotrian, now arranges these energy levels in a different manner (*vide* Naturwissenschaften, Heft 46, p. 953 November 14, 1924). In the case of neutral titanium also, the lowest level found by Kiess and Kiess belong to an *f*- combination, though Meggers reports that Russell has discovered singlet terms. According to Saha, who has got a method of fixing the probable values of ionisation potential within rough limits from an examination of the chromospheric spectrum, it seems to be rather improbable that it would have such a low ionisation potential as 5·4 volts. It must be greater than that of strontium which has an ionisation potential of 5·7 volts.

Leaving this interesting subject for the present, in which there is still sufficient room for further work, we may turn our attention to a critical examination of the applicability of the empirical rules of Sommerfeld and Lande. The selection principle for the rotational quantum number $k \begin{smallmatrix} \nearrow k-1 \\ \searrow k+1 \end{smallmatrix}$ was first stated by Sommerfeld and Rubinowicz, by using the idea of conservation of momentum and energy in a light wave. Sommerfeld supposed that light, as it is emitted, is propogated as a spherical wave with the atom as centre. But if this were true, there would be no pressure of radiant energy on an absorbing gas. But in the case of emission of characteristic light waves by atoms, Einstein proved that light must be radiated as a single quantum in a particular direction. (Phy. Zeits. 1917). Saha also expressed the same view (Astro. Jour. Oct. 1919), that both absorption and emission must be directed quantities ; on this basis he proposed a theory of selective radiation pressure, which accounts for the great heights of the resonance lines of calcium and other ionised elements, in the solar chromosphere. This idea has been developed by Milne with success (Monthly Notices of Royal Astronomical Society, March 1924 page 354) and the average life of the excited Ca^+atoms has been found to be of the order of 10^{-8} secs, as demanded by theory. In recent years A.H. Compton and P. Debye have used the same idea regarding X-rays : They think that a pulse of X-ray has got a momentum $\frac{h\nu}{c}$ and when this passes through matter, it shares this momentum with the electron. Hence when the electron re-emits the wave as scattered pulse, the latter must have a lesser amount of energy and the scattered radiation must have a longer wave length than the primary beam. The idea of directed emission and

absorption which seems to be definitely established is therefore opposed to Sommerfeld's selection principle, but a direct experimental proof of the violation of this principle is obtained in the occurrence of lines of series combination $1x$—mx, where x may stand for s, p, d, or f. This corresponds to a transition number $k \longrightarrow k$, and is therefore a direct violation of Sommerfeld's principle, though a modified form of Sommerfeld's principle allows this combination. But a more flagrant violation of the rule presents itself in the occurrence of lines belonging to combination $1s$—md, where we have got the transition from k to $k+2$. It is said that according to Bohr's Correspondence Principle these lines may occur in an intense electric field. But according to the experiments of Dutta, Foote and Mohler, $1s$—md lines of potassium and sodium occur in emission and absorption, the absorption tube being heated by an ordinary flame, so that the presence of any strong external field is out of question. It appears therefore that the selection principle $k \begin{array}{l} \nearrow k+1 \\ \searrow k-1 \end{array}$ is not strictly correct. All that we can say that these combinations are very strong, and therefore the lines are more intense than those belonging to the combination $k \longrightarrow k+2$.

The violation of the selection principle is also illustrated in the pp', dd', or ff' combinations[1]. Referring back to Lande's classification, this would amount to saying that instead of one horizontal row for either s, p, d, or f, there might be two, three or more. These sets do not correspond to successive values of n in n^r_{kj} and in the case of complex elements, the successive term numbers can no longer be represented by Rydberg's formula. These terms should also be differentiated from

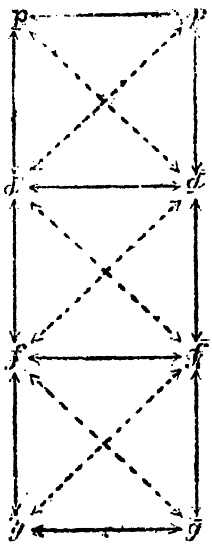
[1] The pp' combinations were first discovered by Saunders and Russell in the spectrum of calcium.

displaced and parallel (Verschobene) terms, first obtained by Paschen and Meissner, in their work on the spectrum of Neon, who pointed out that if a constant number was added to the terms, they could be represented by a Rydberg sequence. The *pp′* sets were first obtained by Catalan in the spectrum of manganese, but they occur very prominently in the spectrum of iron. Laporte calls them the dashed system. One such combination is taken from the spectrum of iron.

		d^1							
	j	0	89·95	1	184·11	2	288·04	3	415·96	4
	0			(60R) 33233·45						
104·49										
	1	(50R) 33039·01		(15R) 33128·96		(100R) 33313·08				
215·54										
	2			(80R) 32914·43		(100R) 33097·53		(100R) 33385·54		
294·40										
	3					(100R) 32803·10		(150R) 33091·17		(125R) 33507·13
411·20										
	4							(100R) 32679·98		(200R) 33095·93

$\triangle\, k = o$; $j = o \longrightarrow j = o$ does not occur in the above multiplet.

For such sets of terms Laporte introduces the selection principle represented in the following diagram :—



The dashed and undashed systems (sets of terms) combine with another as denoted by the full horizontal arrows according to the rule $\Delta k = o$; $\Delta k = \pm 1$ is forbidden. On the other hand combination between similar systems, both dashed and undashed, take place according to the usual rule $\Delta k = \pm 1$; $\Delta k = o$ is forbidden.

In connection with spectrum of iron, we may also introduce the idea of the inverse or the verkehrte terms. We have seen that if we take the components of the triplet system say p_1, p_2, p_3, then applying Lande's rule, these can be written as $n^3_{2\,2}$, $n^3_{2\,1}$, $n^3_{2\,0}$ respectively. Here $p_1 < p_2 < p_3$ or $n^3_{2\,2} < n^3_{2\,1} < n^3_{2\,0}$. Catalan was the first to observe that this rule is violated in the case of two terms of the Cr-spectrum. Sommerfeld was the first to point out that twenty-five terms of the Mn spectrum are inverse terms. An example is taken from the spectrum of chromium.

Designation of terms (according to Catalan)	Value of the terms
$2p_1^a$	.... 27853·6
$2p_2^a$	.... 27844·8
$2p_3^a$	.... 27839·1

In the case of iron, Laporte found that all the terms are verkehrte *i.e.*, $p_1 > p_2 > p_3$. The occurrence of these inverse terms involves great difficulty regarding the assignment of a set of terms to the proper combination of terms of different groups. We cannot be sure whether a group of lines is $p—d$ or $d—p$, and a case of great anomaly is already known in the spectrum of scandium, in which the allocation of certain lines to a definite group of combination of terms by Catalan has not been verified by Grotrian in his absorption experiments. The author has found the following symbolic representation to be of great use in deciding whether a particular combination involves combination between

(*a*) normal—normal terms
(*b*) inverse—inverse terms
(*c*) normal—inverse terms
(*d*) inverse—normal terms

1. Quintet System

	j	d: 0	1	2	3	4
p	1	×	×	×		
	2		×	×	×	
	3		×	×	×	×

The arrows point to the direction in which the frequency decreases.

Here $n^5_{23} < n^5_{22} < n^5_{21}$

$n^5_{34} < n^5_{33} < n^5_{32} < n^5_{31} < n^5_{30}$

$n^5_{23} > n^5_{34}$

$(p-d)$

It may represent a combination between normal p and normal d

or $n^5_{23} > n^5_{22} > n^5_{21}$

$n^5_{24} > n^5_{33} > n^5_{32} > n^5_{31} > n^5_{30}$

$n^5_{34} < n^5_{34}$

$(d—p.)$

a combination between inverse p and inverse d.

II.

		d				
	j	0	1	2	3	4
p	1	×	×	×		
	2		×	×	×	
	3			×	×	×

It may stand for a combination between normal p and normal d.

$p<d$ ....$(d—p)$

or between inverse p and inverse d

$p>d$ ....$(p—d)$

III.

	j	0	1	2	3	4
				d		
p	1	×	×	×		
	2		×	×	×	
	3			×	×	×

It may stand for a combination between normal p and inverse d

$$p > d \ldots\ldots\ldots\ldots\ldots\ldots\ldots (p-d)$$

or inverse p and normal d

$$p < d \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots (d-p)$$

IV.

	j	0	1	2	3	4
				d		
p	1	×	×	×		
	2		×	×	×	
	3			×	×	×

It stands for a combination between normal p and inverse d.

$$p < d \text{ or } \ldots\ldots\ldots\ldots\ldots (d-p)$$

or inverse p and normal d,

$$p > d \text{ or } \ldots\ldots\ldots\ldots\ldots (p-d).$$

CONCLUSION.

We have surveyed the subject from the time of Kirchoff up to the present time, but spaee has not permitted us to deal with the region of X-ray, which now forms a continuous sequence with the visible region on the short wave length side. The subject offers infinite number of problems for investigation, and probably in no branch of physics, the co-operation between the theorist and the experimentalist is so much required as in this subject. Sir J. J. Thompson pointed out in one of his addresses that even the least amount of knowledge about the atom cannot but materially aid the progress of science, but to obtain such knowledge, there must be well-equipped laboratories, and money must be spent ungrudgingly on research.

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